Regional Disease Vector Ecology Profile: The Koreas

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PREFACE

Unless otherwise specified, the information in this DVEP applies primarily to the Republic of Korea (ROK); data regarding arthropod vectors and vector-borne disease within the Democratic People's Republic of Korea (DPRK) is sparse and often not peer-reviewed for accuracy. For those vector-borne diseases that also occur in the DPRK, incidence can be presumed to be higher in the absence of sophisticated programs to suppress vectors or limit disease transmission.

Disease Vector Ecology Profiles (DVEPs) are concise summaries of endemic and reemerging vector-borne and other militarily significant human and zoonotic pathogens that occur in specific countries or regions. DVEPs focus on vector-borne pathogens and associated diseases and emphasize essential epidemiology, vector bionomics, behavior, and pesticide resistance. Selected references to pertinent disease and vector literature are included.

DVEPs are compiled from unclassified literature and are intended to provide historical and current profiles of arthropod-borne disease epidemiology for selected geographical areas. These publications are for official use only.

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The epidemiology of arthropod-borne diseases is constantly changing, especially in developing countries that are undergoing rapid economic development, ecological changes, and those areas experiencing migrations of large refugee populations as a result of civil strife, or natural disasters that require humanitarian assistance. Therefore, DVEPs should be supplemented with recent information on foreign public health status, environmental, political, and economic changes affecting disease risks, and historical and current medical events. DVEPs are designed to complement documents produced by the National Center for Medical Intelligence (NCMI) and every effort is made to ensure their accuracy. Please provide additions, corrections, or suggestions to Chief, Information Services Division at (301) 295-8310/7476, DSN 295-8310/7476 or the AFPMB Webmaster, http://www.afpmb.org/contact.

Current Information: Current disease risk assessments, additional information on parasitic and infectious diseases, and other medical intelligence can be obtained from NCMI, Fort Detrick, Frederick, MD 21701, (301) 619-7574, DSN 343-7511, https://www.ncmi.detrick.army.mil/.

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Museum Support Center (MRC 534)
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The AFPMB is staffed with a Contingency Liaison Officer (CLO) who can help identify appropriate DoD personnel, equipment, and supplies necessary for vector-borne disease and pest surveillance (i.e., collection, identification, and assay of arthropods, etc.) and vector control during contingencies. In addition, the Information Services Division (ISD) can provide bibliographic literature searches of its extensive database on pest management, medical entomology, pest identification, and pesticide toxicology.

AFPMB
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The Information Services Division maintains the AFPMB website that hosts the Literature Retrieval System and the Living Hazards Database. All other AFPMB publications are also available on the website. The website can be accessed at www.afpmb.org

Information on conducting epidemiological surveys, to include assay of human samples, arthropods and rodents for selected pathogens, can be obtained from the US Army Public Health Command Disease Epidemiology Program.

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Korean Peninsula

Figure 1. Map of Korean Peninsula

INTRODUCTION

Democratic People's Republic of Korea

The DPRK occupies the rugged and mountainous Korean peninsula north of a 4-km wide heavily mined demilitarized zone (DMZ) that runs at an acute angle along the 38th parallel, separating the DPRK and ROK. The DPRK is bordered partly on the north by China along the Amnok and Tumen Rivers. The upper northeastern border is shared with eastern Russia along the Tumen River. The peninsula is bordered by the Yellow Sea on the west and the East Sea (formerly Sea of Japan) on the east. The DPRK is divided into nine provinces: Chagang, Yanggang, North Hamgyong, South Hamgyong, Kangwon, North P'yongan, South P'yongan, South Hwanghae, Hwanghae North and three special cities: Kaesong, Namp'o and P'yongyang (see the DPRK Political Map and Google Maps link).

The Korean peninsula is rugged and mountainous (80% of the landscape), especially along the east coast and in the central interior. The DPRK covers about 55% of the peninsula, with a total of 120,540 square kilometers (46,541 square miles), an area slightly smaller than Mississippi. Nearly 65% of the DPRK's total area consists of mountains up to 1,000 m (3,280 ft), while an additional 15% consists of peaks above 1,000 m. The highest peak is Paektu Mountain (2,744 m, 9,003 ft), which is located in the extreme north adjacent to China. The rest of the DPRK consists of narrow to broad river and stream valleys or lowland plains. The DPRK has 8 major ports (Map of DPRK ports).

Winters are long, cold, and dry, especially in the northern interior provinces of Chagang and Yanggang, where temperatures may fall below freezing for as long as five months (avg. January temperature -6ºF or -21.1ºC). The east coast is generally warmer during the winter months, with an average January temperature of 15ºF (-9.4ºC) at Kimch'aek and 25ºF (-3.9ºC) at Wonsan. Average January temperatures on the west coast range from 15.5ºF (-9.2ºC) at Siniju on the Yalu River to 22.6ºF (-5.2ºC) at Haeju. Summers are short and humid with generally uniform temperatures across the country (avg. 70ºF or 21.1ºC). The growing season is only two months long in the extreme north and four in the south. The annual rainfall is 22 - 26 inches (56 - 66 cm) and roughly 60% occurs during the monsoon season, June - September. For more detailed weather information see Air Force Combat Climate Center or Appendix A.

The 24 million DPRK people chiefly occupy the coastal lowlands, particularly in the west and south. Pyongyang, the capital of the DPRK, is the largest city, with a population of 1.3 million. The DPRK people are ethnically homogeneous, speak Korean (with many Chinese loan-words) like their neighbors to the south, and are universally literate. Life expectancy is estimated at 69.3 years.

Traditionally, the country's backbone was agriculture but, in recent years, there has been great industrialization, primarily from foreign investments.

For more information on the DPRK see the CIA Factbook, The Library of Congress, or the US Department of State websites.

Republic of Korea

The ROK covers an area of 38,211 square miles (slightly larger than Indiana), or about 45% of the Korean peninsula, and is bordered to the north by the DPRK; the Yellow Sea is on the west and the East Sea is on the east. China lies westerly across the Yellow Sea and Japan is 115 miles off the southeast coast. The ROK is divided into 9 provinces and 7 metropolitan cities (see ROK Political Map and Google Maps link).

The five major physiographic regions of the ROK are the extensive Central Region, the Eastern Littoral, the Southern Mountain and Valley Region, the Southern Littoral, and the Naktong River Basin (Map of Korean mountains). The Central Region slopes southwestward from the Taebaek Range, encompassing hills and alluvial plains before ending in the much-indented west coast. Along the shallow Yellow Sea, extensive mudflats are exposed to a tidal range of as much as 30 ft (10 m). Despite navigational difficulties, many small ports occur in this area (Map of ROK ports).

The Eastern Littoral is a narrow strip of foothills less than 25 miles wide between the Taebaek Range and the East Sea (Map of Korean mountains). The Sobaek Range, branching from the Taebaek, dominates the Southern Mountain and Valley Region. The Southern Littoral Region includes ridges of the Sobaek Mountains that run into the sea, producing a highly irregular southern coastline. An extensive delta has been formed by the Naktong River, which drains into a complex of basins and floodplains separated by low hills. The Naktong River empties into the East Sea a few miles west of Busan, the second largest city and a major port. The volcanic island of Cheju-do (also transliterated as Cheju) lies 55 miles southeast from the tip of the Korean peninsula, is subtropical at lower elevations, and is distinct from the mainland in ecology and climate.

Climate in the ROK is temperate, with four seasons similar to those of the eastern US. Summers are hot (avg. August temperature 79°F or 26°C), humid and rainy while winters are cold (avg. January temperature 23°F or -5°C), dry and windy. Little snowfall accumulates except at higher elevations in the Taebaek Mountains. Annual precipitation is usually over 40 in. (101 cm), with two-thirds occurring during the rainy monsoon season from June to September. Typhoons with torrential rains usually occur in August, but may occur throughout the year. For more detailed weather information see Air Force Combat Climate Center or Appendix A.

Like the people of the DPRK, the people of the ROK are socially and linguistically homogeneous. In 2013, the population was 48.9 million. This gives the ROK one of the world's highest population densities, with over 9.7 million people in Seoul, 2.5 million in the Incheon area, and 3.4 million people in the port of Busan. Over 10% of the people in the ROK originally came from the DPRK during and after the Korean conflict.

The national language is Korean but many are also partially to very fluent in English, which is taught in all secondary schools. Because Korea was formerly occupied by Japan, many older Koreans also know Japanese. The literacy rate is over 96% due to an excellent public education system that extends from primary schools to the university level. The ratio of medical doctors is 1.7/1,000. Life expectancy (as of 2013) is 79.5 years. Korea's traditional religions are Buddhism and Shamanism, although Confucianism remains a dominant cultural influence.

For more information on the ROK see the CIA Factbook, The Library of Congress or the US Department of State websites.

DISEASE RISK SUMMARY

A number of militarily important vector-borne diseases are known to occur in the DPRK and the ROK. Detailed medical surveillance data from the DPRK are very limited. However, over the past 15 years, considerable effort has been made in the ROK to identify emerging diseases. Table 1 below indicates the relative human health risk posed by a number of vector-borne diseases known to occur on the Korean peninsula (Infectious Disease Risk Assessment Database - DPRK; ROK).

Table 1. Disease risk summary for the DPRK and ROK

	ROK	DPRK
MOSQUITO-BORNE DISEASE		
Malaria	Intermediate	High
Japanese Encephalitis	Intermediate	Intermediate
Filariasis	Low	Unknown
TICK-BORNE DISEASE		
Tick-borne Rickettsioses	Low	Intermediate
Tick-borne Borreliosis (Lyme Disease)	Low	Intermediate
Tick-borne Encephalitis	Low	Low
MITE-BORNE DISEASE		
Scrub Typhus	Low	Intermediate
FLEA-BORNE DISEASE		
Plague	Low	Low
Murine Typhus	Low	Low
Flea-borne Rickettsioses	Low	Unknown
LOUSE-BORNE DISEASE		
Epidemic Typhus	Low	Unknown
Relapsing Fever	Low	Unknown
FLY-BORNE DISEASE		
Diarrhea (bacterial)	High	High
VIRAL INFECTIONS		
Hantavirus with Renal Syndrome (HVRS)	High	High
Rabies	Intermediate	Intermediate
PARASITIC DISEASE		
Soil Transmitted Helminths	Intermediate	Intermediate

MOSQUITO-BORNE DISEASES

There are 56 known species of mosquitoes in the ROK (Appendix A) of which 17 have been implicated as confirmed or probable disease vectors. The geographic ranges of most of these species are likely to include the DPRK. Three major mosquito-borne diseases have historically been of military importance in the Koreas: malaria, Japanese encephalitis and filariasis. Recently, a surveillance program for West Nile virus was conducted on dead birds from all regions of the ROK (Yeh et al., 2011). Over 700 birds representing 72 species were examined with negative results. Turell et al. (2006) demonstrated that *Culex tritaeniorhynchus* and *Culex pallens* mosquitoes collected near Camp Greaves in Gyeonggi Province were both capable of transmitting West Nile virus, indicating the need for continued surveillance for West Nile and other emerging mosquito-borne viruses.

MALARIA

(Infectious Disease Risk Assessment Database - DPRK, https://www.ncmi.detrick.army.mil/product/idra_db.php?co=PRK)

(Infectious Disease Risk Assessment Database - ROK, https://www.ncmi.detrick.army.mil/product/idra_db.php?co=KOR)

Infectious Agent: The protozoan *Plasmodium vivax* was commonly reported during the Korean War (1950-1953), with more than 6,000 cases diagnosed in Korea and an estimated 12,000 cases later diagnosed in the US attributed to exposure in the ROK. Low numbers of *Plasmodium falciparum*, and *Plasmodium malariae* also were reported during the same time period, but those cases were likely imported by UN Forces or Chinese military personnel arriving from malaria-endemic areas of China. Today, *P. vivax* is the only malaria species known to be present on the Korean peninsula.

Epidemiology: Vivax malaria is endemic to the Korean peninsula. Following the Korean War, vast improvements to the Korean economy and quality of housing, and a successful World Health Organization (WHO) malaria eradication program provided the means for the ROK to become malaria free by 1979. In 1993, malaria reemerged along the DMZ when a ROK soldier without any history of travel outside Korea was diagnosed with vivax malaria (Chai et al., 1994). From 1993 through 2000, malaria rapidly increased to a high of 4,142 cases, followed by a rapid decline to 826 cases by 2004 (Figure 2).

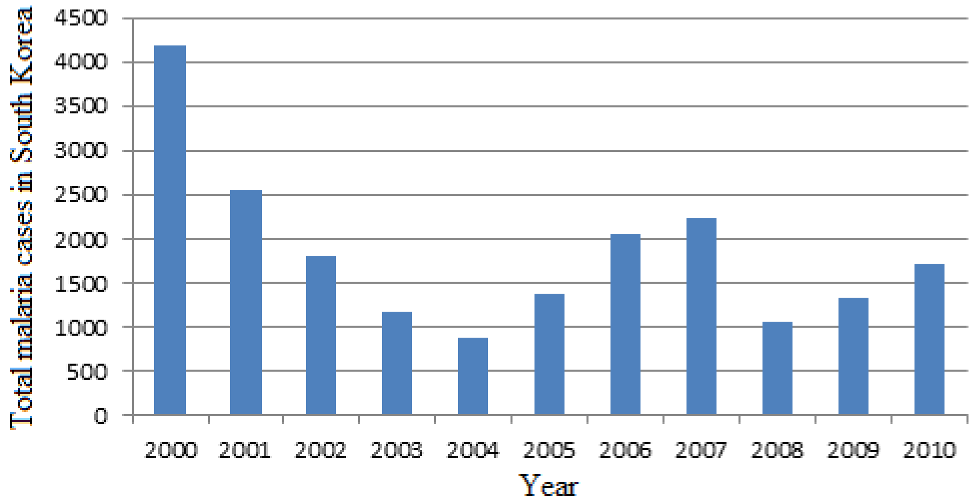

Figure 2. Total malaria cases reported in the ROK 2000-2010.

It is believed that the reintroduction of malaria in the ROK was a result of spillover from the DPRK. The number of malaria cases in the DPRK increased dramatically in the 1990s and reached around 300,000 in 2001 (Figure 3). In 1999, the DPRK government developed a national malaria control program in cooperation with the WHO, to reduce the malaria burden (Chol et al., 2005; Han et al., 2006). According to the 2012 WHO World Malaria Report, the DPRK has been in the pre-elimination phase (the phase between control and elimination) since 2007. The continuing high number of malaria cases reported on the Korean peninsula, with a combined total of 17,598 cases (including 1,343 in the ROK which is in the elimination phase), represents a challenge to the long-term viability of the elimination strategy. Malaria transmission in the DPRK is now largely confined to the southern provinces of Kangwon-do, Hwanghaebukto and Hwanghae-namdo, primarily along the border with the ROK. The WHO indicates that reported infection rates in this area are 1 to 10 per 1000 people per year, although intensity of transmission is not uniform. Farther north, levels of transmission are much lower at rates of 0 to1 per 1,000. Approximately 12% of the DPRK's 23.9 million people live in areas of high transmission risk, particularly in the south. An additional 39% of the population lives in areas of low transmission risk while the remaining 49% live in no-risk areas, which include major cities and the northern part of the country.

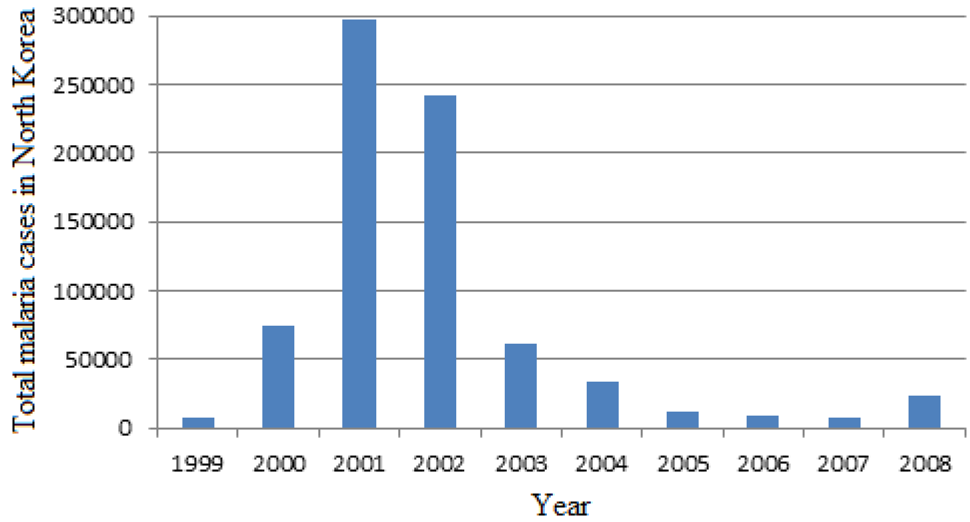

Figure 3. Total malaria cases reported in the DPRK, 1999 to 2008.

In the ROK, the Korea Centers for Disease Control and Prevention (KCDCP) launched the present national malaria control program in 1997. This program includes early case detection and treatment, chemoprophylaxis of soldiers, vector control, PPM, and financial aids to the DPRK for malaria control (Han et al., 2006).

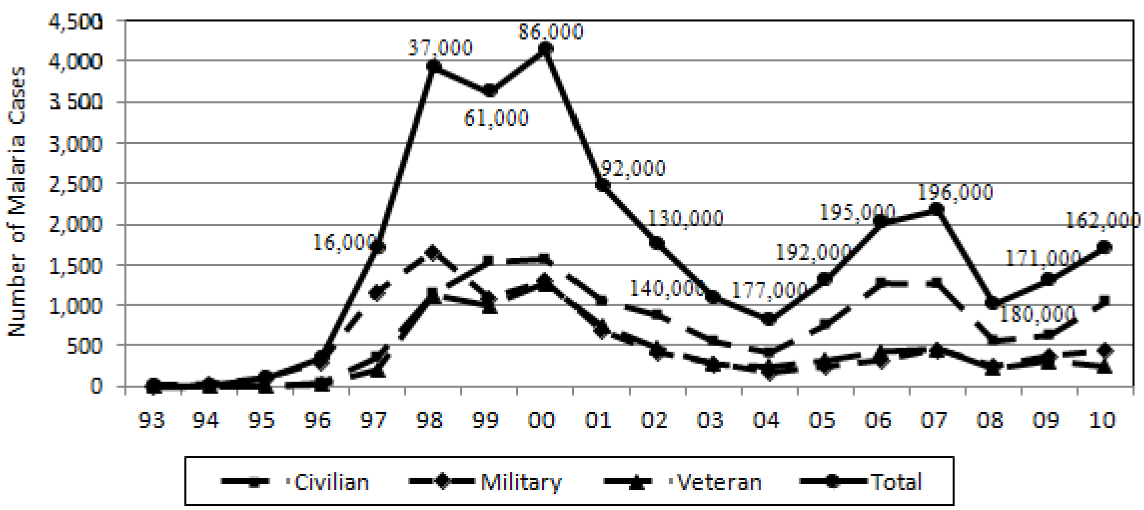

Figure 4. Number of vivax malaria cases diagnosed among ROK civilian, active duty military, and veteran soldiers ($\leq$2 years following retirement/discharge). Numbers shown from 1997-2010 are the approximate number of ROK soldiers placed on chemoprophylaxis annually.

In a study of treatment responses of 484 *P. vivax* malaria patients to chloroquine from 2003 to 2007, Lee et al., (2009a) confirmed chloroquine resistance in 2 patients. This marked the first report of chloroquine resistance in Korea since large-scale chemoprophylaxis began in 1997 (Figure 4). More recently, prophylaxis has consistently failed in many cases despite attainment of sufficiently high plasma concentrations of hydroxychloroquine (HCQ). In addition, the length of time required for the elimination of *P. vivax* from patients' blood by HCQ treatment has increased since 2000 (Lee et al., 2009c).

Associated with the reemergence of vivax malaria, the first post-Korean War case detected in a US soldier attributed to exposure in the ROK occurred in 1992, with subsequent increases in the numbers of malaria cases diagnosed in the ROK or elsewhere, but attributed to exposure in the ROK (Figure 5). Case numbers peaked in 1999 when 53 cases were reported, accounting for more than 68% of all malaria in US forces worldwide. Between 2004 and 2012, 113 cases of vivax malaria were reported from US forces in Korea (Figure 6). Air-conditioned barracks have now replaced poorly maintained tents at Warrior Base, where many of the historic malaria cases were attributed to exposure during training and this has resulted in a decrease in the number of reported cases.

Epidemiological investigations have shown that approximately 60% of vivax malaria contracted in Korea is latent, with blood-stage parasites and disease expressed 6-18 months after infection (T.A. Klein, personal communication). Thus, with typical 1-year deployments to the ROK or other areas of the world, many US Service members are diagnosed with malaria following their return to the US. Figure 7 shows the seasonal distribution of latent and non-latent malaria cases reported between 1999 and 2006.

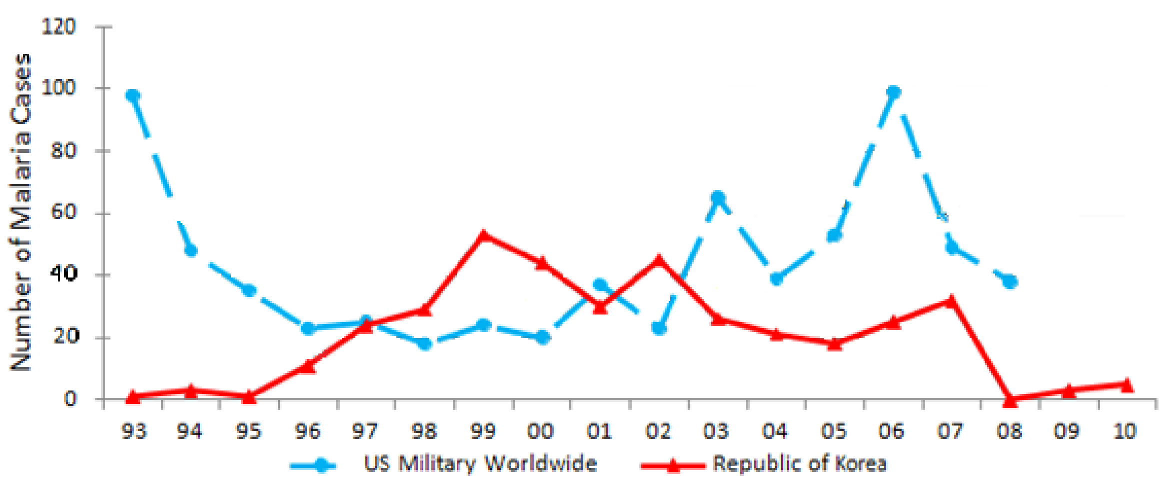

Figure 5. Overall number of malaria cases reported among US military personnel and those deployed to the Republic of Korea from 1993-2010.

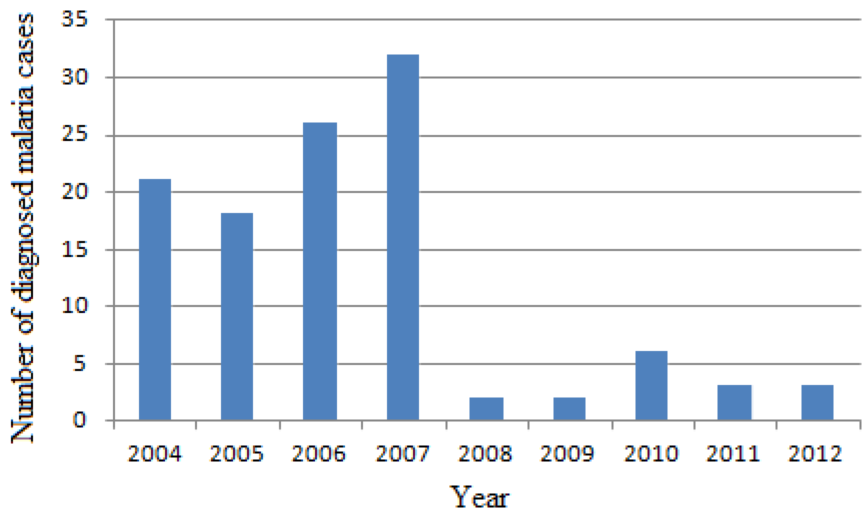

Figure 6. Malaria cases contracted by US Service members in the ROK (Courtesy Armed Forces Health Surveillance Center, 2013).

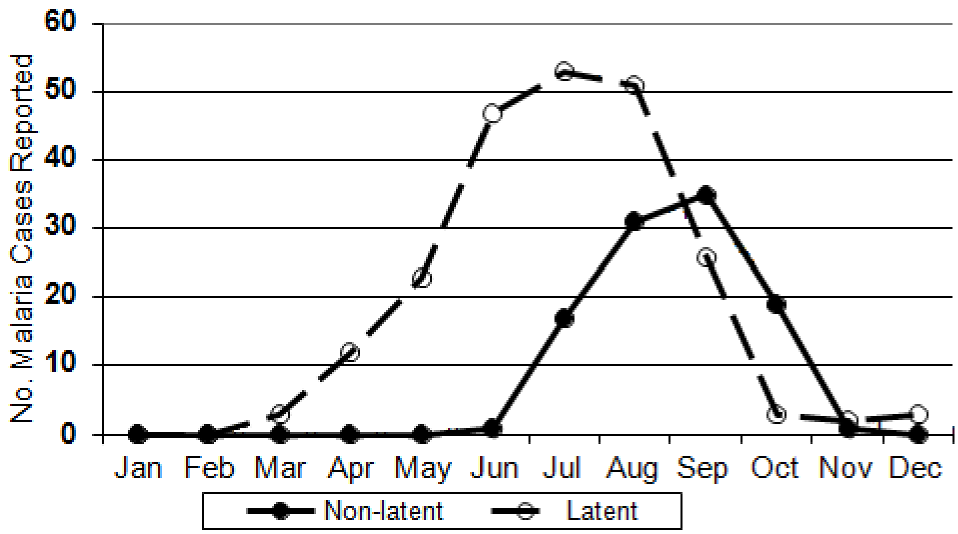

Figure 7. Seasonal distribution of latent (symptomatic 2-24 months after infection) and non-latent (symptomatic <20 days after infection) malaria cases reported in US military personnel (1999-2006), from Klein et al. (2009).

Nishiura et al. (2007) determined that the mean estimates for short-term incubation for *P. vivax* was 26.6 days and long-term was 48.2 weeks. Long-term incubation has been hypothesized to be an adaptation of the malarial parasite to the seasonal population dynamics of the vectors (Nishiura et al., 2007).

Transmission: Human infection occurs through the bite of infected *Anopheles* mosquitoes or transfusion of malaria-infected blood. Soldiers deployed to the ROK should not donate blood for a period of two years after departing the ROK (Armed Forces Blood Program, travel restrictions, http://www.militaryblood.dod.mil/Donors/can_i_donate.aspx)

Eight species of *Anopheles* mosquitoes are found in the ROK: *Anopheles sinensis* sensu stricto (s.s.), *Anopheles pullus* (=*Anopheles yatsushiroensis*), *Anopheles lesteri* (=*Anopheles anthrophophagus*), *Anopheles sineroides*, *Anopheles kleini*, *Anopheles belenrae*, *Anopheles lindesayijaponicus*, and *Anopheles koreicus*. Five of the 8 species (*An.sinensis* s.s., *An. pullus*, *An. kleini*, *An. belenrae*, and *An. lesteri*) can only be identified by PCR techniques (Li et al., 2005). The known and potential vectors of malarial parasites in the ROK belong to the Hyrcanus group (Wilkerson et al., 2003). Foley et al. (2009) constructed ecological niche models for all eight species and concluded that they would occur north of the DMZ as well.

Primary Vectors: *Anopheles kleini*, *Anopheles lesteri* and *Anopheles pullus*

Secondary Vectors: *Anopheles sinensis*, *Anopheles belenrae* and *Anopheles sineroides*

Following the resurgence of malaria along the DMZ, it was thought that malaria would rapidly spread throughout the Korean peninsula based on the large populations of *An. sinensis* that occur there. However, while malaria spread throughout the ROK among ROK veteran soldiers, there has been limited transmission of malaria south of Seoul (Kim et al., 2009c). Subsequently, it was shown that *An. sinensis* is actually a complex of species that cannot be differentiated morphologically (Rueda, 2005). The data showed that the composition of *Anopheles* populations varies between regions in Korea, with *An. kleini* and *An. pullus* accounting for approximately 50% of all *Anopheles* spp. collected near Warrior Base, while *An. sinensis* accounts for >95% of all *Anopheles* spp. collected south of Seoul (W.J. Lee et al., 2007). On the other hand, *An. lesteri*, a malaria vector in China, accounts for a large proportion of the *Anopheles* spp. collected near the northwest coast and islands of the ROK.

In a vector competence study with three species of the Hyrcanus group, Joshi et al. (2009) experimentally infected *An. lesteri*, *An. sinensis* and *An. pullus* with a Korean isolate of *P. vivax.* Susceptibility to infection was based on the ability to develop oocysts in the midgut and sporozoites in salivary glands. Oocyst infections in the midgut were detected eight days post-feeding in all three species. *An. lesteri* was highly susceptible, with oocysts detected in 100% of test mosquitoes compared to *An. sinesis* (87%) and *An. pullus* (83%). When salivary glands of the infected mosquitoes were examined, nine out of 14 *An. lesteri* (64%) and two out of 19 *An. sinensis* (11%) contained sporozoites. All the examined salivary glands of 6 *An. pullus* lacked sporozoites.

In a study on the comparative susceptibility of *An. kleini*, *An. lesteri*, and *An. sinensis* to *P. vivax*, sporozoites in salivary glands at 14 days post-feeding were detected in *An. kleini* and *An. lesteri*, with numbers high enough to initiate infection, while no sporozoites were detected in the

salivary glands of *An. sinensis* (Joshi et al., 2011).

Analysis of limited data indicates that Tongilchon, approximately 2 km from Warrior Base, near the DMZ, is a reservoir for malaria. *Anopheles kleini* and *An. pullus* are likely the primary vectors for *P. vivax*, based on evidence that these two species develop large numbers of sporozoites in their salivary glands (Figure 8). While greater numbers of *An. sinensis* were PCR positive, evidence suggests that many do not develop sufficiently high numbers of sporozoites to efficiently transmit malaria (Joshi et al., 2011).

<u>Vector Bionomics</u>: Throughout the Korean peninsula, most *Anopheles* spp. larvae are commonly collected from flooded rice fields (cultivated and uncultivated), low-lying grassy depressions, ponds, and stream and irrigation ditch margins from early May to occasionally early November (depending upon the onset of the cool fall season), with overall populations peaking in July and August. Ree (2005) found *An. sinensis* breeding in a wide variety of habitats, including rice fields, ditches, streams, irrigation canals, marshes, ponds, and ground pools. Sithiprasasna et al. (2005) collected larvae of *An. sinensis*, *An. pullus* and *An. lesteri* most frequently in rice paddies followed by ditches, flooded areas, ground pools, wheel tracks, swamps, irrigation canals, and stream margins. *Anopheles sineroides* was found most commonly in flooded areas. Kim et al. (2007b) found larvae of *An. sinensis* chiefly in water seepage springs and marshes, *An. pullus* in rice fields and stream margins, *An. belenrae* in pond and lake habitats, and *An. lindesayi* in pools of fast running streams. Rueda et al. (2006) collected anophelines from 204 locations across the ROK between 1998 and 2004 and provide detailed information on larval habitats.

Adult anophelines typically rest in outdoor sheds and stables, but they also rest in gardens and among vegetation. Biting activity for most species normally begins at dusk, peaks before midnight, and continues throughout the night with a small peak just before sunrise. Most species overwinter as unfed adults although a few may overwinter as eggs or early instar larvae.

Anecdotal data suggest that *An. sinensis* s.s. prefers to feed on cattle, but will readily bite humans outdoors or inside lighted houses. There is evidence that *An. kleini* prefers to feed on humans, although it is also commonly collected in cowsheds. Because the species status of members of the Hyrcanus group was only recently determined, there are insufficient data to confirm biting behavior patterns for each species. However, overall, biting normally begins at dusk, peaks around 22:00 hrs, and continues throughout the night with a small peak just before sunrise. According to Kim et al. (2007b), *An. kleini* population numbers peak during late spring and early summer, whereas *An. sinensis* peaks during late summer and fall.

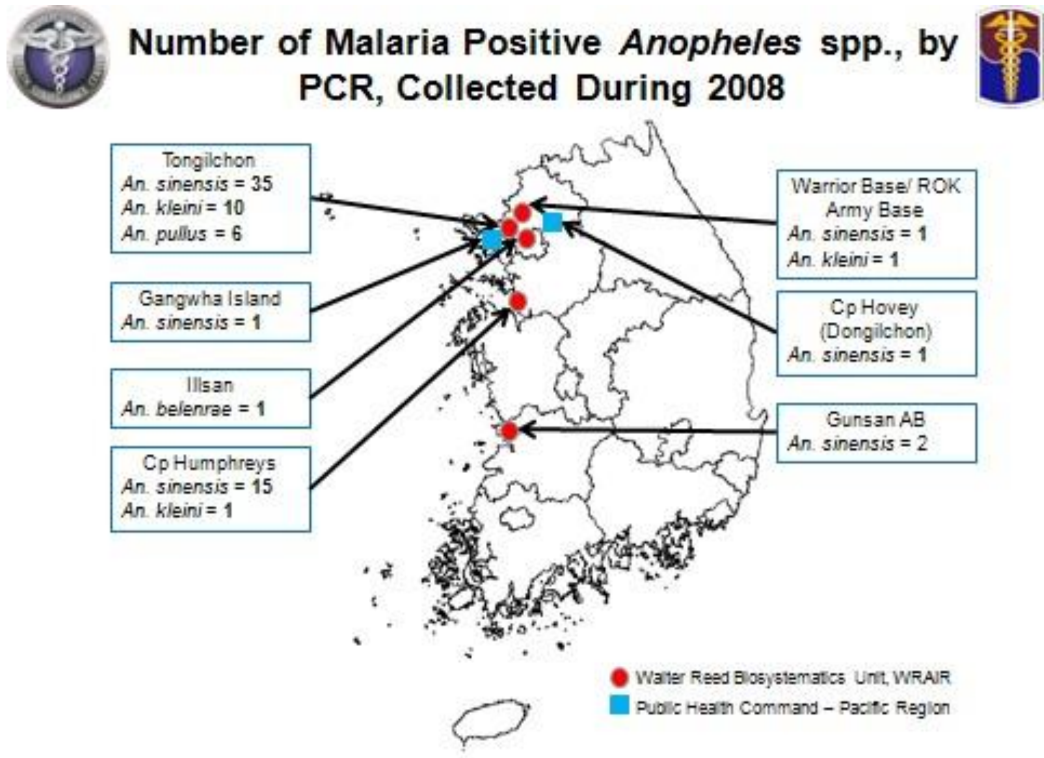

Figure 8. Distribution of field collected *Anopheles* spp. positive for vivax malaria by polymerase chain reaction (PCR).

Lee at al. (2007) studied the distribution of malaria vectors in high malaria risk locations near the DMZ and low-risk areas near the southern tip of the Korean peninsula. Overall, *An. sinensis* s.s. was the most common mosquito captured from malaria high-risk areas (63.3%), followed by *An. kleini* (24.7%) and *An. pullus* (8.7%). *Anopheles sinensis* accounted for 96.8% of all mosquitoes collected in malaria low-risk areas, whereas *An. kleini* accounted for only 2.7%. *An. pullus* was not captured in the malaria low-risk area. *Anopheles lesteri*, *An. belenrae*, *An. sineroides*, and *An. koreicus* made up only 3.3% of the total anophelines captured from malaria high-risk areas. This evidence suggests that population densities of *An. kleini* and *An. pullus* are much higher in malaria high-risk areas compared with malaria low-risk areas, where *An. sinensis* s.s. may account for >95% of all *Anopheles* collected.

Based on New Jersey light trap collections near the DMZ, Lee et al. (2007) reported that *An. kleini* and *An. pullus* population densities were relatively high compared with other US military installations south of Seoul where *An. kleini* and *An. pullus* accounted for <3% of all *Anopheles* collected. The higher proportions of *An. kleini* (53.1%) and *An. pullus* (25.1%) collected by Mosquito Magnet® traps near human concentrations at Warrior Base and Camp Bonifas, compared with nearby animal bait resting collections (*An. kleini* 24.7% and *An. pullus* 8.7%),

suggest a greater affinity of these species for human biting than *An.sinensis* (16.6 and 63.3%, respectively).

Little information is available from the DPRK as to what mosquito species are involved in malaria transmission and the relative abundance and distribution of potential malaria vector populations. However, *Anopheles belenrae, An. pullus* and *An. sinensis* have been recorded in the DPRK from 2 provinces (Hwanghae and Pyongyang) by Rueda and Gao (2008). Foley et al. (2009) produced ecological niche models for 8 anopheline species using collection location data from the ROK that predicted suitable habitats in southern DPRK. The island of Baengnyeong-do is the westernmost point of the ROK and is located 16 km from the southwestern coast of the DPRK. Foley et al. (2011) collected 257 anophelines from there in July 2007. *Anopheles lesteri* was the most frequently collected (49.8%), followed by *An. sinensis* (22.6%), *An. pullus* (18.7%), *An. kleini* (7.8%), and *An. belenrae* (1.2%). The overall sporozoite rate was 3.1%, with the highest rates observed in *An. kleini* (15.0%), *An. sinensis* (5.2%), and *An. lesteri* (1.6%). No sporozoite-positive *An. pullus* or *An. belenrae* were observed. Their results extended the known distribution and potential role in malaria transmission of *An. kleini, An. lesteri,* and *An. sinensis,* for an area previously considered to be at a low risk for contracting vivax malaria.

JAPANESE ENCEPHALITIS (JE)

(Infectious Disease Risk Assessment Database -DPRK, https://www.ncmi.detrick.army.mil/product/idra_db.php?co=PRK)

(Infectious Disease Risk Assessment Database - ROK, https://www.ncmi.detrick.army.mil/product/idra_db.php?co=KOR)

Infectious Agent: *Flavivirus* (Japanese Encephalitis Virus – family Flaviviridae)

Epidemiology: Japanese encephalitis (JE) is a viral mosquito-borne disease that affects the central nervous system and may be fatal or leave people with mild to severe brain damage (neurological deficiencies). Though only a small fraction of persons infected with JE virus develop clinical manifestations of encephalitis, these manifestations are so severe that the disease is greatly feared, especially when it occurs in epidemic form. Not only is the encephalitis associated with a high death rate, but severe permanent neurologic sequelae occur in a high proportion of patients who survive (Rosen, 1986).

Japanese encephalitis was first identified in the ROK from an American soldier at Inchon in 1946 (Sabin et al., 1947; Kim et al., 2011). In 1949, JE became a notifiable disease in the ROK and 5,616 cases resulting in 2,729 deaths (49%) were reported. After 1950, outbreaks of several thousand cases were reported periodically every 2-3 years. The largest outbreak occurred in 1958 with 6,897 cases. Between 1958 and 1968, there were 2,000 to 3,000 cases reported

annually (Sohn, 2000).

In 1967, the Korean government instituted a massive JE immunization program for school-aged children, which significantly changed the epidemiology of JE in Korea (Kim et al., 2011). Since the inception of the program, the number of JE cases has dropped significantly, averaging less than 5 cases annually as shown in Figure 9 (Seo et al., 2013).

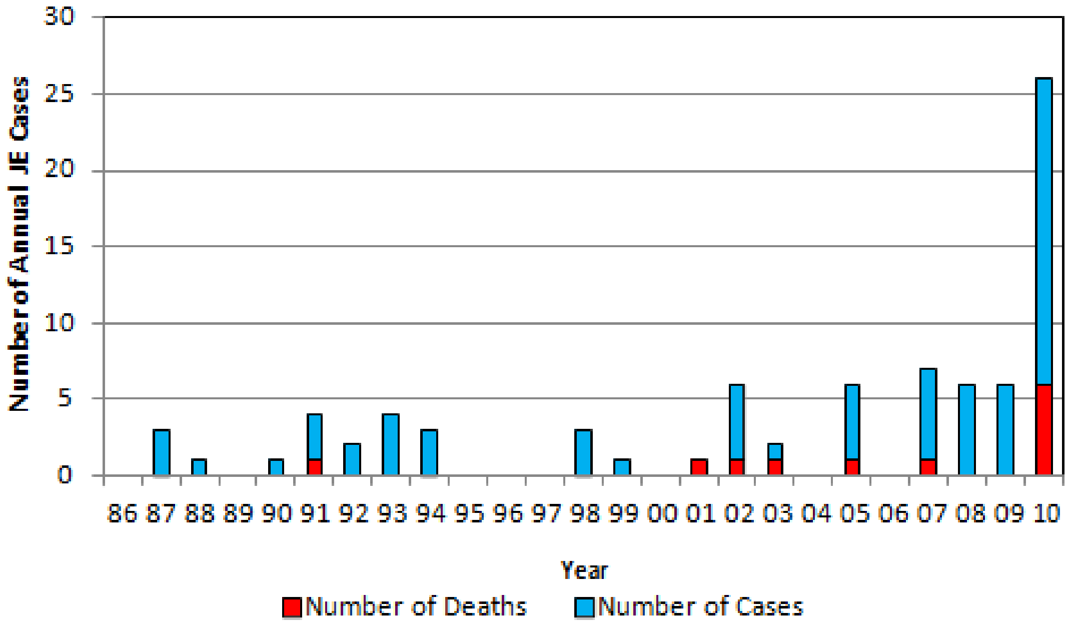

Figure 9. Number of Japanese encephalitis cases and associated deaths among ROK populations from 1986-2010 (Seo et al., 2013).

The exception was in 2010, when an outbreak of JE occurred with 26 reported cases, including seven JE-associated deaths, among the ROK population (Seo et al., 2013); Figure 10 shows the distribution of cases. These cases followed a rainy season that extended through September. Most of the cases were among people over 40 years of age who had not been enrolled in the mandatory childhood vaccination program. Two cases, 14 and 28 years of age, should have been in the mandatory childhood vaccination program, but it is unknown whether they received the vaccine. For current policy on JE vaccines for military members, consult the Defense Health Agency's Immunization Healthcare Branch website: https://www.vaccines.mil/Japanese_encephalitis; for others consult the CDC's JE vaccine website: http://www.cdc.gov/japaneseencephalitis/vaccine/index.html.

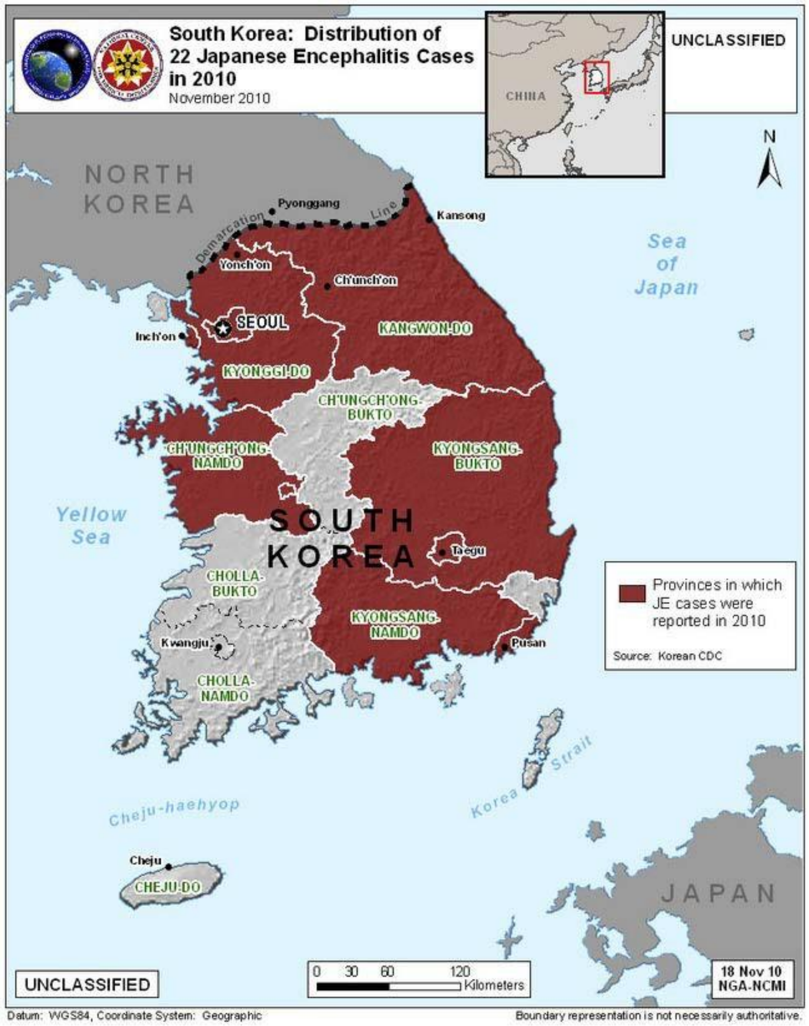

Figure 10. Distribution of JE cases in 2010.

Since 1984, when JE vaccine coverage reached almost 90%, only a few sporadic cases have occurred in young adults or the elderly. In addition to the vaccination program, several factors contributed to the decline of JE. Improved living conditions, effective public health programs, the widespread use of agricultural insecticides, a decrease in the population density of vector mosquitoes by the removal of mosquito habitats, and the modernization of agricultural practices, such as improved sanitary conditions on pig farms in rural areas, have all contributed to reducing the risk for human infection (Sohn, 2000).

Historically, most JE cases occurred in southern Korea. Today, the distribution of JE cases is primarily in the northern half of the ROK. Very limited information regarding the epidemiology of JE is available from the DPRK.

In a review of US Military Health System beneficiaries during the period 2000 to 2009, there were

no hospitalizations reported due to JE, and no hospitalizations in the Pacific region reported due to arboviral encephalitides (Armed Forces Health Surveillances Center, 2010; Armed Forces Health Surveillance Center, 2013).

Vaccination of the local population against JE does not diminish the risk to unvaccinated US military forces, despite dramatic reductions in local human incidence. Vaccination does not interrupt the cycle of JE transmission between mosquitoes and pigs or birds and therefore does not reduce the number of infected mosquitoes to which unvaccinated US personnel could be exposed. Tsai (1993) suggested that due to the mandatory childhood vaccination program and underreporting of asymptomatic to mild cases, the official reporting of JE cases in the ROK may significantly underestimate the JE health threat.

The Korea National Institute of Health (KNIH) conducts mosquito surveillance, but it does not provide information on relative vector infection rates. Instead, when JE vector populations exceed 50% of the collected mosquitoes, the KNIH issues public JE alerts, reminds citizens to use all means to protect themselves from mosquito bites, and encourages high-risk groups to obtain vaccinations. However, the areas where the Korean workforce conducts sampling are often not the same areas of interest as those of the US military forces.

Additionally, the KNIH conducts serosurveillance for the presence of JE antibodies and infection from slaughtered pigs at selected sentinel sites. The KNIH reports the results in public news releases, which emphasize vaccination and preventive medicine measures (PMM). However, these data do not reflect focal infections because 1) sentinel sites are limited, 2) only data from slaughterhouses are reported, not the pig farm sites where the transmission occurred, and 3) pig farms are isolated and not evenly distributed in Korea. Despite, its limitations, this program serves as a valuable warning system. Prior to the immunization program, it was observed that approximately 2 weeks after the pigs were found to be serologically positive for JE virus, mosquito samples were identified as positive, and shortly thereafter, focal outbreaks of JE occurred in human populations.

In summary, the lack of specific antiviral treatment, the high case/fatality ratio (up to 30%), and the potentially severe and permanent clinical effects of JE make prevention (e.g., elimination of mosquito habitats, personal protective measures (PPMs) against mosquito bites, immunizations) a high force health protection priority (Armed Forces Health Surveillance Center, 2010).

Transmission: JE virus is maintained in the environment through a transmission cycle involving vector mosquitoes and birds of the family Ardeidae (i.e., herons and egrets). The virus has been isolated in nature from a variety of animals, and both wild and domestic species have been shown to develop viremia high enough to infect mosquitoes. Pigs serve to amplify the transmission cycle, producing extremely high viremias that in turn may infect large numbers of blood-feeding mosquitoes. Breeder sows are often immunized because JE infections cause spontaneous abortion in those about to litter. However, young pigs raised for slaughter usually

are not immunized since virus infections do not affect their health or weight gain. Humans are considered to be dead-end hosts as they rarely develop sufficient viremia to infect mosquitoes.

The greatest threat for JE transmission is where vector mosquitoes occur in large numbers in association with wetland rice farms, pig farms, and the presence of large wading birds. Military personnel residing or training near such habitats are at greatest risk of infection. Risk assessments conducted for JE at US military installations and training sites should consider five factors:

1) Seasonality: Vector populations usually peak in late August and September and most cases of JE are observed in late August through October
2) Proximity of swine farms (vector mosquitoes may fly 3 to 5 km to feed)
3) Proximity to rice paddies
4) Proximity to unmanaged low-lying wet areas with tall grasses
5) Relative abundance of large wading birds

As the demographic structure, distribution, and concentration of US military forces change in Korea, surveillance for vector-borne diseases must remain a priority. Continuing surveillance of mosquito populations, their infection rates, and coordination with the KNIH and Korea Center for Disease Control and Prevention is necessary to delineate the risks and reduce the threat of JE to US military and civilian personnel.

Primary Vectors: The primary vector of JE virus in the ROK is *Culex tritaeniorhynchus*. The virus was also recently isolated from *Culex bitaeniorhynchus* within the DMZ at Daeseong-dong. Other mosquitoes, including *Armigeres subalbatus* and *Culex pipiens*, have also been implicated as potential vectors, but their roles are largely unknown. *Culex tritaeniorhynchus* is by far the most important mosquito involved over most of the geographic range of the virus (Rosen, 1986).

Mosquito surveillance for JE virus has been conducted periodically around US and ROK military installations. Studies to determine the minimum field infection ratio (MFIR) [(number of positive pools/number of female mosquitoes)/1,000] of JE virus from *Cx. tritaeniorhynchus* conducted between 1982 to 2004 in the ROK ranged from a low of 0.11 to a high of 3.3 (Turell et al., 2003; Kim et al., 2007b). It is important to remember that the MFIR estimates the lower bound of the infection rate by assuming that only one infected mosquito exists in a positive pool.

During the 2010 outbreak year, Kim et al. (2011) showed the prevalence of JE virus infections among *Cx. tritaeniorhynchus* within the DMZ at Daeseong-dong was nearly 8.46/1,000 mosquitoes compared to all other surveyed sites (3.03/1,000). The virus was detected in 50/207 (24.2%) pools of *Cx.tritaeniorhynchus* and 1/45 (2.2%) pools of *Cx. bitaeniorhynchus*, whereas all other culicine species were negative for JE virus. Positive *Cx. tritaeniorhynchus* were observed on all collection dates between the end of August and mid-October. Few *Cx.*

tritaeniorhynchus were collected during the second half of October, and none were positive for JE virus. One *Cx. bitaeniorhynchus* pool (collected in September) was positive for JE virus, representing the first report incriminating this species as a potential vector in the ROK.

Vector Bionomics: *Culex tritaeniorhynchus*, the primary vector of JE virus, breeds in rice fields, ground pools, and marshes that are characterized by open standing water and that are somewhat stagnant. This mosquito is very adaptable and has also been observed breeding in artificial containers, such as barrels and cement tanks (Yi and Wildie, 1983).

Using data from mosquito collections made between 2002 and 2008, Richards et al. (2010) found an overall statistically significant linear relationship between rice field density and *Cx. tritaeniorhynchus* abundance around 17 military installations in the ROK. Because many of the US installations and military training sites in the ROK are surrounded by rice paddies, and large numbers of *Cx. tritaeniorhynchus* are observed through monitoring by various trapping methods (Kim et al., 1999; Kim et al., 2003a; Turell et al., 2003; Kim et al., 2007b) increased vigilance and monitoring are required to ensure that US personnel use PPMs. Such measures include the use of bednets, repellents and permethrin impregnated uniforms or other appropriate clothing when outdoors at night to reduce mosquito bites and transmission of JE virus in these high-risk areas.

Vector populations are normally low in May through June, but rapidly increase and peak in the summer. Wildie and Yi (1984) found that *Cx. tritaeniorhynchus* populations reach their peak in August, sharply decline in September, and continue to decline into October. Population levels of *Cx*. *tritaeniorhynchus* can reach very high levels. Klein (personal communication) reported that trap catches with a Mosquito Magnet™ exceeded 6000 mosquitoes per trap night at Gunsan Air Base. Vector populations are lower near the DMZ than in the south, but trap catches may still exceed 1000 mosquitoes per trap night during peak periods. Baik and Joo (1991) extensively studied *Cx. tritaeniorhynchus* in Gyeongsang-butko Province between 1984 and 1990. The average trap catch per month over the 7-year period is shown in Figure 11.

Throughout much of its geographical range, *Cx. tritaeniorhynchus* obtains the majority of its blood meals from cattle, and because bovines do not produce sufficient viremia to infect mosquitoes, they may impede transmission of JE virus (van den Hurk et al., 2009). High porcine feeding rates are generally associated with high pig populations, and *Cx. tritaeniorhynchus* will readily feed on pigs when available (Pennington and Phelps, 1968). Examining 735 blood-fed *Cx. tritaeniorhynchus* collected from 3 locations in the ROK, Self et al. (1973) found 59.5% fed on pigs followed by 36.9% on cattle. Humans account for only a small proportion (less than 5%) of blood meals for most *Culex* vectors of JE virus in Asia (van den Hurk et al., 2009).

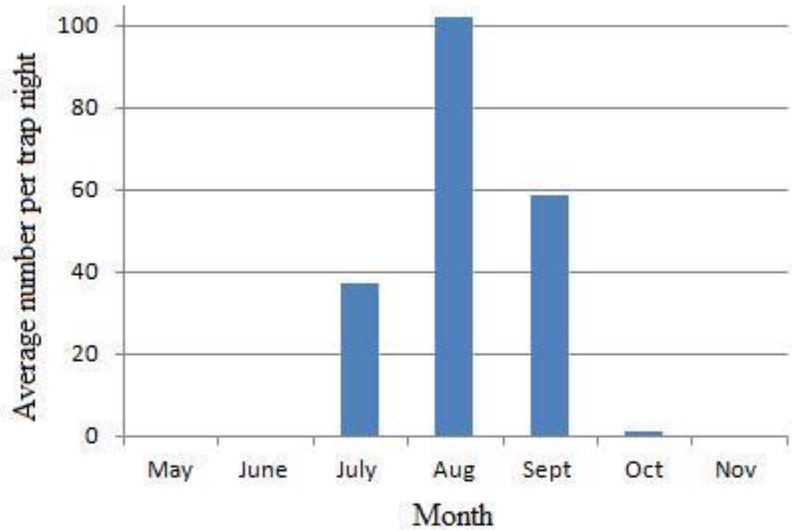

Figure 11. Average number of *Cx. tritaeniorhynchus* collected per trap night over a 7-year period in Gyeongsang-butko Province (from Baik and Joo, 1991).

FILARIASIS

The microfilarial nematode *Brugia malayi* once was considered endemic in Cheju Province, ROK with foci in rural southern coastal provinces and in Yongju, Kwangju, and Busan. With improved living conditions, mosquito control, and treatment of infected persons, this parasitic disease is no longer considered to be a medical threat in the ROK (Korea Centers for Disease Control and Prevention, 2007). Through steady efforts combining investigation and treatment, filariasis was officially declared eradicated from the ROK by the WHO in 2008 (Cho et al., 2012).

The Korea CDC carried out a surveillance program for lymphatic filariasis from 2002 to 2006 in Cheju-do, Gyeongsangbuk-do and Jeollanam-do, areas in which the disease had been endemic. Their clinico-epidemiological surveillance survey confirmed that transmission of lymphatic filariasis in Cheju-do, Gyeongsangbuk-do, and Jeollanam-do had been terminated (Cheun et al., 2009). Surveillance of vector mosquitoes in former endemic areas between May and October 2009 confirmed the absence of *Brugia malayi* but revealed high population levels of the vectors, *Ochleratus togo*i and *An*. (*hyrcanus*) group mosquitoes. Continued surveillance is warranted to monitor for potential re-introduction of filariasis (Cho et al., 2012).

TICK-BORNE DISEASES

Background Information

Ticks have been implicated as vectors of a number of human and animal pathogens in the Koreas. There are 22 species of ticks and 18 tick-borne pathogens (some of which are zoonoses, infectious agents transmissible under natural conditions from wild or domestic vertebrate animals to humans) identified from the Republic of Korea (Appendix C and Table 2). In 1971, US Army personnel assigned to the 406th Medical Laboratory, Camp Zama, Japan published a comprehensive work on the systematics and bionomics of ticks in Japan and the ROK, even though limited Korean tick data were available for inclusion (Yamaguti et al., 1971). This document, however, remains useful because many of the ticks found in Japan are also found in the ROK, and it is still the primary document for identifying Korean ticks. Additional information on tick-borne diseases, surveillance methods and control techniques can be found in AFPMB Technical Guide 26, Tick-borne Diseases: Vector Surveillance and Control.

Researchers in the ROK have found a number of tick-borne pathogens within ticks and their rodent host populations, but few human cases have been documented. Possible explanations for the lack of human cases include: humans are not the preferred host of the primary vectors, human avoidance of tick habitats, and lack of familiarity in the medical community with diseases caused by tick-borne pathogens, issues with ordering the correct diagnostic test, and the fact that tick-borne diseases are not reportable medical events in Korea. Very few tick attachments are reported by US military personnel serving in Korea, and the DoD Insect Repellent System (http://phc.amedd.army.mil/topics/envirohealth/epm/Pages/DoDInsectRepellentSystem.aspx) is very effective at preventing tick bites and thus tick-borne diseases. Hence, tick-borne disease risk is low in Korea and is likely to be even lower with use of uniform and skin repellents (see Appendix G – Personal Protective Measures).

From an entomological perspective, very little was known about Korean ticks during the Korean War. Ticks were reported as being uncommon, and very few military personnel complained of tick bites (Traub et al., 1954). Since the Korean War, the ROK has shifted from an agricultural society to an industrial and technology-dominant one, which has led to massive urbanization of metropolitan areas such as Seoul, Busan, Pyeongtaek, and Daegu. During the late 1960s and early 1970s, the ROK government directed the replanting of trees on hills and mountains, which had been deforested during the Japanese occupation of 1910 to 1945. These environmental changes may have increased tick populations in those areas by increasing tick survival due to increased numbers and density of suitable hosts. Many urban Koreans spend weekends hiking in mountainous areas where the trails and paths are generally well worn and free of tick harborage (vegetation and leaf litter). However, when hikers go off the beaten path into forested areas covered with leaf litter and patches of grass, the potential for human-tick interaction greatly increases. Still, urbanization appears to have reduced the overall exposure potential of the Korean population to ticks.

In the ROK, small mammals (e.g., rodents and insectivores) and their associated ticks are hosts to a number of zoonotic pathogens: spotted fever group rickettsiae (SFGR) (Lee et al., 2003), *Ehrlichia* and *Anaplasma* spp. (Chae et al., 2003), *Bartonella* spp. (Kim et al., 2005), *Borrelia burgdorferi* (Park et al., 1992; Kee et al., 1994a), and tick-borne encephalitis virus (Kim et al., 2008; 2009). Humans are an incidental host as a result of coming into contact with ticks during agricultural, outdoor construction and maintenance, military, and recreational activities.

Numerous studies involving tick and rodent surveys have been conducted across the ROK to monitor tick-borne disease activity. Between 2004 and 2008, Kim et al. (2010a) conducted rodent-borne disease surveillance at 25 ROK and US operated military sites in Gyeonggi and Gangwon Provinces. The striped field mouse, *Apodemus agrarius*, accounted for over 90% of the 5,397 small mammals trapped. *Ixodes nipponensis* was the most frequently collected tick species, accounting for over 98% of the 4,575 specimens collected and appears to be the most likely vector of tick-borne zoonoses observed in rodents and insectivores captured in Gyeonggi and western Gangwon Provinces. *Ixodes nipponensis* may also play an important role in the transmission of tick-borne pathogens to humans in the ROK because this species is frequently reported from patients (Cho et al., 1994; Ryu et al., 1998; Ko et al., 2002; Chang et al., 2006).

In a recent study comparing the effectiveness of sweeping and dragging for tick collection, Chong et al. (2013) sampled in 4 distinct habitat types in Gyeonggi Province and concluded that tick-host associations are central to the habitat distribution of ticks. *Haemaphysalis longicornis* was collected primarily in habitats consisting of grasses and other herbaceous vegetation and is associated with the large wild and domestic mammals that use these habitats. *Ixodes nipponensis* adults and nymphs were more frequently collected in forest habitats, indicating their association with hosts that use forest habitats for refuge but perhaps feed or seek prey in open grassy areas. Hosts of *I. nipponensis* larvae and nymphs range from small to medium-sized mammals, while nymphs and adults blood feed on medium to large-sized mammals. *Haemaphysalis flava* were most often collected from conifer and mixed forest habitats where there is a higher density of small to medium-sized mammals and migratory and indigenous birds (Yamaguti et al., 1971; Kim et al., 2009b; 2010a). Neither sweeping nor dragging methods were effective at collecting large numbers of *I. nipponensis*. However, this species was the predominant tick collected in small mammal trapping studies conducted in tall grasses and herbaceous vegetation in northern Gyeonggi Province. In general, *Haemaphysalis* spp. are the predominant ticks collected in tick drag surveys, while *I. nipponensis* is the primary species collected from small mammals in the ROK.

Tick surveillance conducted between 2004 and 2013 revealed that ticks are abundant and easily collected, observations that are thought to be due to the ecological transition from treeless to forested mountains and pasture habitats, which began in the late 1960s and has continued under the ROK's green plantation program (Kim et al., 2010a, 2013). Currently, large numbers of ticks can be collected from many sites, including short-grass and leafy-forest habitats throughout the ROK. For example, US Army tick surveys in 2007 resulted in the collection of approximately

6,800 ticks representing 6 species from Cheju Province and along the southern coast in Jeollanam and Gyeongsangnam Provinces (Ko et al., 2010).

Operational field conditions for military forces during a prolonged armistice are typically different from intensive combat operations, such as during the Korean War. Generally speaking, military personnel operating during noncombat periods can expect to have a relatively high level of sanitation and personal hygiene, living and operating out of established base camps. These situations allow for frequent body inspections for ticks to reduce the potential for pathogen transmission and the incidence of tick-borne disease. In contrast, during major combat operations, military personnel in forward areas are generally not able to sustain the same level of hygiene (even with periodic rotations), due to extended and austere battlefield conditions, as they would during noncombat operations. Consequently, their exposure to zoonotic tick-borne and other vector-borne pathogens is increased. In addition, they may occupy areas that have higher tick populations, e.g., forested areas during combat operations, and therefore have increased contact with the ground and vegetation harboring questing ticks. Similarly, the civilian population may experience displacement, homelessness, reduced sanitation, increased exposure to vectors and disease, and elevated disease levels, thus increasing the risk of spreading disease through vectors to military forces operating in the region.

Table 2. Human and animal pathogens detected and associations with suspected tick vectors in the Republic of Korea (After Sames et al., 2009a).

Pathogen	Vector(s); Reference(s)
Anaplasma bovis	*H. longicornis*; Kim et al., 2003b
Anaplasma phagocytophilum	*H. longicornis*, *I. persulcatus*; Kim et al., 2003b
Anaplasma platys	*H. longicornis*; Kim et al., 2006
Babesia spp.	*H. longicornis*; Cho et al., 2002a; Kim et al., 2007a
Bartonella elizabethae	*H. longicornis*; Kim et al., 2005
Bartonella grahamii	*I. turdus*; Kang et al., 2013
Bartonella spp.	*H. longicornis*; Kim et al., 2005
Borrelia afzelii	*I. nipponensis*; Lee et al., 2002
Borrelia burgdorferi sensu lato	*I. granulatus*, *I. nipponensis*, *I. persulcatus*; Kee et al., 1994a
Borrelia garinii	*I. persulcatus*; Takada, 2003
Borrelia turdi	*I. nipponensis*, *I. turdus*; Kang et al., 2013
Borrelia valaisiana	*I. nipponensis*; Masuzawa et al., 1999
Coxiella spp.	*H. longicornis*; Lee et al., 2004
Ehrlichia canis	*H. longicornis*; Kim et al., 2006
Ehrlichia chaffeensis	*H. longicornis*, *I. persulcatus*; Kim et al., 2003b; 2006; Lee et al., 2005
Ehrlichia ewingii	*H. longicornis*; Kim et al., 2006
Theileria sergenti	*H. longicornis*; Kang and Jang, 1989
Tick-borne encephalitis virus	*H. longicornis*, *H. flava*; Kim et al., 2008; Ko et al., 2010
Severe Fever Thrombocytopenia Syndrome	*H. longicornis*; Yu et al., 2011

SPOTTED FEVER GROUP RICKETTSIA

The SFGR belonging to the genus *Rickettsia* are obligate intracellular and gram-negative bacteria with a worldwide distribution, including all of the ROK (Jang et al,. 2004). Rickettsiae are typically divided into two antigenic and genetic groups: the SFGR and the typhus group rickettsiae (TGR). Both groups have a global distribution, although individual species may be associated with more defined geographic foci because of the ecological restrictions of their reservoirs or vectors (Parola et al., 2005b). In recent years, there has been increasing recognition of rickettsial diversity and disease around the world. To date, at least 13 SFGR, including *Rickettsia rickettsii*, *R. siberica*, *R. conorii*, *R. africae*, *R. japonica*, *R. akari*, and *R. felis*, have been associated with human disease ranging from mild or asymptomatic infection to severe disease leading to death (Forshey et al., 2010). In foci of endemicity, SFGRs cause sporadic outbreaks in Japan, southern China, and eastern Russia—countries that surround the Koreas (Choi et al., 2005).

The pathogens can be transmitted transstadially (from one life stage to the next) and transovarially (from parent to offspring) in ticks, fleas, and mites, and they circulate between wild vertebrates and arthropods that play an important role in the maintenance of these bacteria in nature. A high infection rate of rickettsial diseases among domestic animals and pets has been found using serologic and molecular surveys all over the world, demonstrating a high risk of human infection. (Fan et al., 1987; Horta et al., 2004; Nicholson et al., 2010). Humans are incidental hosts that become infected through the bite of infected vectors (Kelly et al., 2002).

JAPANESE SPOTTED FEVER

Japanese spotted fever is an emerging tick-transmitted infectious disease characterized by fever, headache, shaking chills, skin eruptions, tick bite eschars, erythemas, and malaise (Mahara, 1997). In Japan, the agent has been shown to be associated with *Dermacentor taiwanensis*, *Haemaphysalis formosensis*, *H. flava*, *H. longicornis*, *Ixodes ovatus*, and *I. persulcatus*, many of which also occur in the ROK and the DPRK (Jang et al., 2004).

In the ROK, antibodies against *R. japonica* were first detected by an indirect fluorescent antibody test in serum samples collected from patients experiencing the early stage of febrile illness during December 1992 to November 1993 (Jang et al., 2004). In this study, nearly 20% of patients (676/3,401) were seropositive for *R. japonica*. Japanese spotted fever infections were found to occur from spring to winter, with monthly incidence peaking between March (31.62%) and April (30.25%), and a second peak occurring in July (30.18%). Based on province of patient residence, the results indicated that Japanese spotted fever occurs throughout the ROK.

The first confirmed human case of Japanese spotted fever in the ROK was reported in 2004 (Chung et al., 2006). In a retrospective study, Choi et al. (2005) utilized molecular techniques to

examine serum specimens from 200 ROK patients who experienced febrile illness between 1993 and 1999. Spotted fever group rickettsiae agents were detected in 23 samples, including *R. japonica* and a number of previously unreported rickettsiae. Other SFGR identified included: *R. akari*, causative agent of rickettsial pox which is transmitted by the bite of *Allodermanyssus sanguineus*, a mite ectoparasite of the domestic mouse (*Mus musculus*); *R. connori*, the etiologic agent of Mediterranean spotted fever or boutonneuse fever, which is transmitted by ticks; and *R. felis,* associated with flea-borne spotted fever.

Evidence of SFGR infections in rodents has been reported by numerous Korean researchers. Baek et al. (1999) reported 5/97 (5.1%) *Apodemus agrarius* and 4/39 *Rattus norvegicus* were seropostive for SFGR. Kim et al. (2006) reported 5.8% of *Apodemus agrarius* were infected with a *Rickettsia* closely related to *R. japonica.*

Korean researchers have also examined bloodfeeding arthropods for SFGR infections. In a study of trombiculid mites removed from wild rodents in southern Jeolla Province, *R. japonica*, *R. akari*, *R. conorii*, *R. felis*, and isolates very similar to *R. australis* were detected by PCR and sequence analysis (Choi et al., 2007). *Rickettsia japonica* was also identified by PCR in *H. longicornis* ticks collected by flagging from vegetation in Chungju, Chungchongbuk-Do (Lee et al., 2003). However, infected mites removed from rodents have not been scientifically proven to transmit the pathogens.

Kim et al. (2006) reported on a study of ticks collected from rodents and vegetation at 19 sites near the demilitarized zone (DMZ) and other US military installations during 2001 through 2003. *Rickettsia japonica* was not detected. However, 28/1,638 pools of *H. longicornis* ticks were positive for a closely related strain previously isolated from ticks in China.

While confirmed human cases of infection with SFGR remain rare in the Korean population, the results of the rodent and tick surveys, combined with previous serologic and molecular evidence in humans, suggest that illness caused by SFGR in the ROK may be misdiagnosed. This is supported by a retrospective study (Baek et al., 1988) demonstrating that a large proportion of patients with suspected hemorrhagic fever with renal syndrome (HFRS) were actually serologically positive for SFGR and negative for HFRS.

TICK-BORNE BORRELIOSIS (LYME DISEASE)

(Infectious Disease Risk Assessment Database -DPRK, https://www.ncmi.detrick.army.mil/product/idra_db.php?co=PRK)

(Infectious Disease Risk Assessment Database - ROK, https://www.ncmi.detrick.army.mil/product/idra_db.php?co=KOR)

Infectious Agent: Spirochete bacterium, *Borrelia* spp. Since the original isolation of *B.*

burgdorferi as the causative agent of Lyme disease in the US in 1982, a large number of related strains have been identified worldwide. *Borrelia burgdorferi* sensu lato is now known to include at least 10 additional species (Lee et al., 2000a).

Epidemiology: Tick-borne borreliosis is an emerging disease in East Asia, and the epidemiological picture of the disease in the region is incomplete. Several species of *Borrelia* have been isolated from ticks and small rodents in the ROK. *Borrelia garinii* was isolated from *Ixodes persulcatus and Apodemus agrarius* in Chungcheongbuk and Gangwon Provinces (Park et al., 1993). *Borrelia afzelii* was isolated from *I. persulcatus, I. nipponesis*, *I. granulatus* and *A. agarius* captured in Gangwon, Jeollanam and Chungcheongbuk Provinces (Lee et al., 2000a; Kee et al., 1994b). *Borrelia valaisiana* was identified from *I. nipponensis* collected in Haenam, located at the southern tip of the Korean peninsula (Masuzawa et al., 1999). A recently identified but unnamed strain was isolated from *I. granulatus* and mice collected in Haenam (Lee et al., 2000b). Because the principal vectors of tick-borne borreliosis are widespread in East Asia, the disease probably occurs in the DPRK as well. The spirochetes are maintained in foci of endemicity by tick-mammal associations involving a relatively few species of ticks in the genus *Ixodes* and primarily *Apodemus agrarius*, the most common rodent encountered.

Very few human cases of tick-borne borreliosis have been documented from the ROK. In a review of 1,897 serum samples from suspected cases between 2005 and 2009, 53 cases were confirmed. Of these, 37 were suspected to have been contracted in the ROK in Gyeonggi, Gangwon, Jeollabuk, Chungcheongbuk, Chungcheongnam, Gyeongsangbuk and Gyeongsangnam Provinces (Figure 12) (Park et al., 2011). Moon et al. (2013) investigated two confirmed cases contracted by individuals who were herb collecting in the mountains of Gangwon Province during late May and early June, 2012. The greatest risk for infection is during spring, summer and fall, when ticks are active.

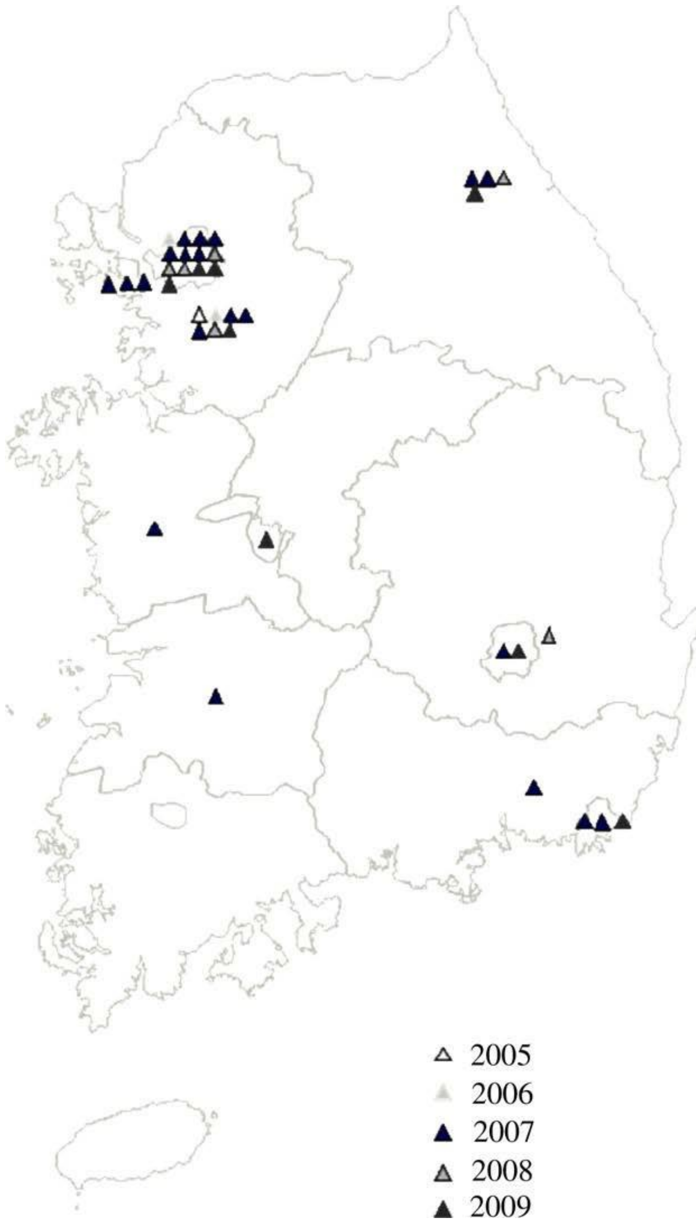

Figure 12. Distribution of 37 domestic tick-borne borreliosis cases, 2005-2009 (Park et al., 2011).

Similar to syphilis, the clinical disease manifests itself in acute and chronic stages. Initially there is a highly characteristic expanding skin lesion (erythema migrans) that develops in about 60% of cases. Flu-like symptoms usually occur about the same time. Weeks to months after initial infection, cardiac, neurological or arthritic symptoms and other joint abnormalities may occur and persist for years. Treatment in the late stages of tick-borne borrelial disease can be difficult, and chronic infection can be very debilitating. Early recognition and treatment are critical. Based on information from clinicians, the main symptoms of tick-borne borreliosis infection

seen in the ROK are rash and fever (66.0%), neurological manifestations (30.2%), and arthritis (5.7%) (Park et al., 2011). In the ROK, laboratory tests for tick-borne borreliosis are conducted only by the Division of Zoonoses in KNIH.

Transmission: All known primary vectors of tick-borne borreliosis are hard ticks of the genus *Ixodes*, subgenus *Ixodes*. Infective spirochetes are transmitted by tick bite. Nymphal ticks usually transmit the disease to humans. Transmission of the pathogen often does not occur until the tick has been attached for at least 24 hours, so early tick detection and removal can prevent infection. *Borrelia burgdorferi* has been detected in mosquitoes, deer flies and horse flies in the northeastern United States and Europe, but the role of these insects in transmitting borreliae appears to be minimal. Rodents, insectivores and other small mammals maintain spirochetes in their tissues and blood and infect larval ticks that feed on them. Infection with more than one genotype has been found in ticks as well as vertebrate reservoirs. Spirochetes are seldom passed transovarially from female ticks to offspring. Small mammals vary in their relative importance as reservoir hosts in different geographic regions. Field mice in the genera *Apodemus* and *Clethrionomys* are the chief reservoirs across Eurasia. In Korea, *A. agrarius* appears to be a primary reservoir host (Park et al., 1993; Lee et al., 2002). Experimental studies suggest that birds are poor hosts of the spirochetes that cause tick-borne borreliosis and play an insignificant role as reservoirs, but are involved in the circulation of *Borrelia* spp. principally as disseminators of infected ticks to new areas. Large mammals, especially wild pigs and deer, are important as hosts of adult ticks and essential to completion of the life cycle of the vector, but are unimportant as reservoirs of the pathogen.

Potential Vectors: *Ixodes persulcatus*, *I. nipponensis*, *I. granulatus*

Borrelia garinii and *B. valaisiana* have been isolated from *I. persulcatus* and *I. nipponensis*, while *B. afzelii* has been isolated from *I. nipponensis* and *I. granulatus* (Park, 1993). Borrelial isolates from *I. nipponensis* ticks have been reported only in Korea and it appears to be one of the main vectors carrying *B. afzelii* and *B. valaisiana*. This species has also been implicated in cases of human tick bites (Ryu et al., 1998; Cho et al., 1994). In the ROK, *B. afzelii* has been isolated from ticks collected from the eastern, central, and southern regions, and *B. garinii* from the southern regions (Moon et al., 2013).

Vector Bionomics: Larvae and nymphs of *I. persulcatus* are associated with a wide variety of small mammals and birds. Adults parasitize larger wild and domestic animals and man. *I. persulcatus* is collected mainly along the eastern alpine range, while *I. nipponensis* is widely distributed across the ROK (Kee et al., 1994a). *Ixodes granulatus* was found frequently in the southern regions, including Jullanam Province (Moon et al., 2013).

TICK-BORNE VIRAL ENCEPHALITIS

(Infectious Disease Risk Assessment Database - DPRK, https://www.ncmi.detrick.army.mil/product/idra_db.php?co=PRK)

(Infectious Disease Risk Assessment Database - ROK, https://www.ncmi.detrick.army.mil/product/idra_db.php?co=KOR)

Infectious Agent: Tick-borne Encephalitis (genus *Flavivirus*)

Epidemiology: Tick-borne Encephalitis (TBE) is a zoonotic viral infectious disease involving the central nervous system. In humans, the disease most often manifests as meningitis, encephalitis, or meningoencephalitis. A mild fever also can occur. Long-lasting or permanent neuropsychiatric sequelae are observed in 10-20% of infected patients. There is no treatment or specific drug therapy and care is supportive only. Risk of infection can be greatly reduced by use of personal protective measures. Although human cases of TBE have not been reported in Korea, the number of patients with encephalitis caused by unknown agents is increasing each year (Kim et al., 2008).

Tick-borne Encephalitis virus is divided into three subtypes - Far Eastern (Russian spring-summer encephalitis [RSSE], Western (Central European encephalitis [CEE]), and Siberian - that demonstrate various severities of disease (Lindquist and Vapalahti, 2008). Infections of RSSE frequently result in very severe encephalitis with mortality rates from 8 to 54%, while CEE infections caused by the Western subtype induce milder symptoms with mortality rates of 1 to 5% (Grešíková and Calisher, 1988).

Korean TBE isolates from wild *Apodemus agrarius* rodents have been identified as the Western subtype by sequence and phylogenetic analyses (Yun et al., 2011). This is in contrast to TBE virus strains from neighboring countries, including China, Japan, and northeastern Russia, that belong to the Far-Eastern subtype (Kim et al., 2008). In China, the Far Eastern TBE virus subtype is mostly reported from the northeastern forests and mountains of Changbai, Jinlin Province, Daxing'an, Inner Mongolia Province, and Xiaoxing'an, Hei Longjiang Province, which extend into the DPRK (Lu et al., 2008).

Transmission: As a result of the previously described tree planting policy established in the 1960s, hills and mountains that were formerly almost barren are now covered with dense young deciduous and conifer forests. This has dramatically altered the ecology of these areas, creating the potential for increases and variation of animal populations and their associated ectoparasites (Ko et al., 2010).

The main reservoirs of the virus are ticks or ticks and small mammals in combination, including rodents and hedgehogs, and possibly birds. Tick-borne Encephalitis infections usually occur between March and November, which follows tick activity. Researchers in Korea have identified

molecular evidence of TBE virus infections in ixodid ticks and small mammals. The virus can also be acquired by ingesting infected and unpasteurized milk; cases of this type are known as biphasic milk fever. It has been demonstrated that the virus can be isolated from infected milk stored at 4C for up to 14 days and from butter for 60 days (Grešíková and Calisher, 1988).

In a study conducted at 25 localities across the ROK, a total of 13,053 ticks were collected during 2011- 2012 (Yun et al., 2012). *Haemaphysalis longicornis* (90.8%, 11,856/13,053) was the most abundant species in this study, followed by *H. flava* (8.8%, 1,149/13,053), *I. nipponensis* (0.3%, 42/13,053), and *I. persulcatus* (0.05%, 6/13,053). Ten pools containing TBE virus PCR-positive ticks were identified from Gunsan in Jeollabuk-do Province, Chuncheon and Sokcho in Gangwon-do Province, and Cheju on Cheju Island. Tick species that were positive included *H. longicornis* (7), *H. flava* (2), and *I. nipponensis* (1). These results indicate that TBE virus may be endemic at these localities in the ROK, and *H. longicornis*, *H. flava*, and *I. nipponensis* may be potential vectors of the TBE virus Western subtype.

In a study conducted during 2005 and 2006 in 5 southern Korean provinces, 2,460 ticks were collected from vegetation, the ground and various hosts (Kim et al., 2009b). Four primary tick species were collected *H. longicornis* (1,714); *H. flava* (452); *Haemaphysalis japonica* (107), and *I. nipponensis* (187). Tick-borne Encephalitis-positive ticks were identified from Yangpyeong (two sample pools), Dongducheon (three sample pools), Pyeongchang (five sample pools), and Jeongsun (two sample pools). Prevalence of TBE virus was 0.2% in *H. longicornis*, 0.8% in *H. flava*, 0.9% in *H. japonica* and 1.6% in *I. nipponensis*.

In another study in southern Korea and Cheju Island, 6,788 ticks were collected and 4,077 were tested by PCR for TBE virus (Ko et al., 2010). *Haemaphysalis longicornis* was the most frequently collected species (73.4%; n = 4,984), followed by *H. flava* (22.4%; n = 1,523), *H. phasiana* (3.2%; n = 216), *Amblyomma testudinarium* (0.4%; n = 25), *I. nipponensis* (0.4%; n = 24), and *I. turdus* (0.2%; n = 16). TBE virus was detected on Cheju Island in two of the six collected species: *H. longicornis* (5) and *H. flava* (1). The minimum field detection rates (assumes a minimum of one infected tick/pool) of TBE virus were 0.17% for *H. longicornis* and 0.14% for *H. flava.* All positive isolates from Cheju Island belonged to the Western subtype.

In the northern ROK, four of 38 tick pools from Dongducheon in Gyeonggi-do Province and Jeongseon in Gangwon-do Province, and five of 24 wild rodents from Hapcheon and Gurye were positive for TBE virus by PCR (Kim et al., 2008). Two virus isolates were recovered from *Apodemus agrarius* from the Hapcheon region, suggesting that TBE virus may be maintained in this common species in Korea. Partial nucleotide sequences from 4 ticks and 5 rodent samples showed that Korean TBE strains clustered with the Western subtype, rather than the Far Eastern or Siberian subtypes.

Potential Vectors: In the ROK, *Haemaphysalis longicornis*, *Haemaphysalis flava*, *Haemaphysalis japonica*, *Ixodes nipponensis* and *Ixodes persulcatus* have been incriminated as potential vectors of TBE (Yun et al., 2012). The same species can be presumed to be vectors in the DPRK.

OTHER TICK-BORNE PATHOGENS

EHRLICHIOSIS

Ehrlichia species are strict intracellular gram-negative bacteria that parasitize monocytes, granulocytes or platelets and are responsible for various vector-borne diseases in animals as well as humans in different parts of the world (Paddock and Childs, 2003). Human ehrlichiosis is an emerging tick-borne disease in the ROK and the impact of this disease on human populations is unknown, as most cases go unreported. In the absence of reports, the same situation can be inferred to be occurring in the DPRK. Ehrlichiosis encompasses disease caused by both *Ehrlichia chaffeensis* and *Anaplasma phagocytophilum* (human granulocytic ehrlichiosis). Several species of *Ehrlichia* and *Anaplasma* have been identified in the ROK (Kim et al. 2006; Heo et al., 2002), and the possibility of ehrlichiosis should be considered in the differential diagnosis of febrile patients with a history of tick bites in the ROK and DPRK.

ANAPLASMOSIS (HUMAN GRANULOCYTIC EHRLICHIOSIS)

Although no cases of human anaplasmosis (formerly called human granulocytic ehrlichiosis or HGE) have been recorded, seroepidemiological findings suggest the presence of the disease in the ROK population. Heo et al. (2002) identified antibodies against *Ehrlichia chaffeensis* and *Anaplasma phagocytophilum* among serum samples from patients with febrile illnesses of otherwise unknown etiology in the ROK by an indirect fluorescent antibody test and Western blotting.

Infectious Agent: Bacterium, *Anaplasma phagocytophilum* (formerly known as *Ehrlichia phagocytophilia*)

Epidemiology: *Anaplasma* infects white blood cells (neutrophils) causing an acute febrile illness. Other symptoms of anaplasmosis include headache, malaise, body aches and, rarely, encephalitis or meningitis. Although no human cases of anaplasmosis have been recorded in Korea, antibodies for the pathogen were detected in >11% of 270 rural ROK residents tested (Park et al., 2003). *Anaplasma phagocytophilum* has been isolated from the Korean water deer, *Hydropotes inermis argyropus*, suggesting it may serve as a reservoir. *Anaplasma phagocytophilum* was detected in *I. persulcatus* ticks, *Apodemus agrarius* and the Ussuri shrew, *Crosidura lasiura*, during an extensive survey near or at US military installations and training sites in the ROK (Kim et al., 2006).

Transmission: The pathogen is transmitted to people through the bite of infected ticks.

Potential Vectors: *Haemaphysalis longicornis, Ixodes persulcatus*

HUMAN MONOCYTIC EHRLICHIOSIS

In 2000, the first suspected case of *Ehrlichia chaffeensis* was reported in an active-duty American Soldier stationed in the ROK (Sachar et al., 2000). Heo et al. (2002) subsequently identified antibodies against *E. chaffeensis* from patients with febrile illnesses in the ROK.

Infectious Agent: Bacterium, *Ehrlichia chaffeensis*

Epidemiology: An acute febrile illness. *E. chaffeensis* is likely maintained by a diverse range of wild and domestic animals. Although few human cases of ehrlichiosis have been recorded in Korea, antibodies for the pathogen were detected in ≥ 9% of 270 rural ROK residents tested (Park et al., 2003). In Korea, *E. chaffeensis* has been detected in dogs and the peripheral blood of spotted deer (*Cervus nippon*), suggesting they may serve as reservoirs (Yu et al., 2008). In addition, *E. chaffeensis* has been identified in *Haemaphysalis longicornis* and *Ixodes persulcatus* ticks and *Apodemus agrarius* from several provinces in the ROK using molecular methods (Kim et al., 2003b; Lee et al., 2005; Kim et al., 2006; Lee and Chae, 2010).

Transmission: Salivary glands of *H. longicornis* ticks collected from grazing cattle in Cheju Island were tested for *E. chaffeensis*. Of 463 ticks tested, 56 (12.1%) were positive for *E. chaffeensis*. In addition, two (0.4%) were co-infected with both *E. chaffeensis* and *A. bovis* (Lee and Chae, 2010). Detection of the pathogen in salivary glands provides additional support for *H. longicornis* as a vector. In Gyeonggi Province, 26 out of 611 (4.3%) *H. longicornis* ticks collected from rice fields and Army training sites tested PCR positive for *E. chaffeensis* (Lee et al., 2005). DNA sequence analysis indicated a close sequence similarity to *E. chaffeensis* isolates from the US. *Amblyomma testudinarium*, which also occurs in Korea, has been implicated as a possible vector in China (Cao et al., 2000).

Potential vectors: *Haemaphysalis longicornis*, *Ixodes persulcatus*

OTHER TICK-BORNE DISEASES

TULAREMIA

(Infectious Disease Risk Assessment Database - DPRK, https://www.ncmi.detrick.army.mil/product/idra_db.php?co=PRK)

(Infectious Disease Risk Assessment Database - ROK, https://www.ncmi.detrick.army.mil/product/idra_db.php?co=KOR)

Infectious Agent: Bacterium, *Francisella tularensis*

Epidemiology: Tularemia occurs in the ROK and the DPRK and rare cases are possible. Outbreaks involving multiple cases have been reported from neighboring countries in the region.

Although ticks are capable of transmitting the pathogen, the majority of human infections are from consuming contaminated water or handling infected animals, and infection from ticks is uncommon in Asia. Tularemia can produce an untreated case-fatality rate of 5 - 15% from pulmonary disease or symptoms similar to typhoid. Jellison type B, or *Francisella tularensis* biovar *palaearctica*, is less virulent, and even without treatment produces few fatalities. Tularemia may be clinically confused with typhoid fever, plague and other infectious diseases.

Symptoms of infection vary but they usually produce an ulcer or papule at the site of inoculation, with swelling of the regional lymph nodes. Early symptoms include fever, headache, abdominal pain, cough and vomiting. Ingestion of organisms in contaminated food or water may produce a painful pharyngitis, vomiting and diarrhea. Inhalation of infectious material may be followed by severe pulmonary disease. Tularemia is easily treated with antibiotics. Long-term immunity follows recovery, although reinfection has been reported.

Transmission: Recent studies in Slovakia indicate that tick-borne transmission of tularemia is rapidly becoming more common. Other methods of acquiring the disease include direct inoculation into the skin from an infected animal bite or scratch. Person-to-person transmission does not occur, although congenital infection has been reported.

Potential Vectors: *Francisella tularensis* has been isolated from at least 60 species of ticks, including members of the genera *Amblyomma*, *Dermacentor*, *Haemaphysalis*, *Hyalomma*, *Ixodes* and *Rhipicephalus*; indeed, it appears that almost any ixodid tick, as well as some argasids, can be infected with and transmit this disease. Additionally, a broad range of other blood-sucking arthropods, including deer flies, mosquitoes and possibly fleas, are considered important vectors of infection among non-human vertebrates. Transstadial transmission of *F. tularensis* occurs in susceptible ticks, but transovarial passage has not been confirmed. Ticks transmit the disease to rabbits, the primary zoonotic hosts of the disease, and such other mammals as field mice and voles.

SEVERE FEVER WITH THROMBOCYTOPENIA SYNDROME (SFTS)

Infectious Agent: Bunyavirus (genus *Phlebovirus*)

Severe Fever with Thrombocytopenia Syndrome (SFTS) is an emerging disease caused by a Bunyavirus (genus *Phlebovirus*) that was first described from Central and Northeast China in 2010, where it was isolated from patients who presented with fever, thrombocytopenia, leukocytopenia, and multiorgan dysfunction. A small number of SFTS cases have also recently been reported from Japan and the ROK.

Epidemiology: The first fatal cases of SFTS were diagnosed in South Korea in 2013 (Kang, 2013). The Korea Centers for Disease Prevention and Control (KCDPC) reported that a 63-year-

old woman, who died in August 2012 after suffering fever and diarrhea, was infected with the SFTS virus. The patient died 10 days after she was hospitalized after being bitten by a tick while working in a field in Gangwon Province. A second fatal case occurred in May 2013 involving a 73- year-old farmer from Cheju Island who was hospitalized with symptoms of severe fever, diarrhea and vomiting following a tick bite (Kang Hyun-kyung Korea Times, 2013-05-21). In China in 2010, presence of the virus was confirmed in 171 patients from six central and northeastern provinces. Nearly all cases occurred from May to July and involved farmers living in wooded and hilly areas and working in the fields before the onset of disease. The virus was detected in 10 of 186 (5.4%) *H. longicornis* ticks collected from domestic animals in the areas where the patients lived (Yu et al., 2011). The virus apparently infects a wide range of animals. In two SFTS-endemic counties of Shandong Province antibodies to the virus were detected in 328 (69.5%) of 472 sheep, 509 (60.5%) of 842 cattle, 136 (37.9%) of 359 dogs, 26 (3.1%) of 839 pigs, and 250 (47.4%) of 527 chickens. Severe Fever with Thrombocytopenia Syndrome virus was also isolated from sheep, cattle, and dogs. Phylogenetic analysis of the virus isolates obtained from the sheep, cattle, and dogs in this study and from *H. longicornis* ticks showed >95% homology with SFTS virus isolates obtained from patients from the same region, which suggests a potential link of SFTSV infections among humans, domesticated animals, and ticks (Niu et al., 2013). Zhao et al. (2012) reported that 2/237 (0.8%) healthy persons in Yiyuan County, Shandong Province, were seropositive for SFTS and concluded that subclinical SFTSV infections or a relatively mild form of SFTS illness may occur in humans.

Transmission: The disease can be transmitted from person to person through contact with an infected patient's blood or mucous (Liu et al., 2012). The first fatal cases of SFTS diagnosed in the ROK in 2013 followed tick bites (Kang, 2013), although conclusive evidence of tick transmission has yet to be demonstrated.

Potential Vectors: *Haemaphysalis longicornis*. While the virus has been isolated from *H. longicornis* ticks, conclusive evidence of tick transmission has yet to be demonstrated.

BABESIOSIS

Infectious Agent: *Babesia ovata oshimensis*

Epidemiology: The first case of human babesiosis from the ROK was described in 2007; cases in the DPRK have not been reported. The parasites that cause this malaria-like disease reproduce in red blood cells, but unlike the malaria parasites, they lack an exo-erythrocytic phase, so the liver is usually not affected. Babesiosis is a severe and sometimes fatal disease; the clinical syndrome can include fevers up to 105°F (41°C), shaking chills, myalgia, fatigue and long-lasting jaundice secondary to hemolytic anemia. In some cases, symptomless parasitemia may persist for months or years.

Transmission: Little is known about the biology of babesiosis transmission in the ROK and the DPRK. Elsewhere, transmission is largely through nymphal ticks and from late spring through early fall.

Potential Vectors: *Babesia ovata oshimensis* has been isolated from *Haemaphysalis longicornis* in the ROK. Although not yet confirmed, this tick is a suspected vector of human babesiosis in the Koreas. It is also possible that *Ixodes persulcatus* may be a vector.

Q FEVER

Infectious Agent: Bacterium, *Coxiella burnetti*

Epidemiology: Q fever is an acute, febrile rickettsial disease contracted primarily by inhalation of airborne pathogens or contact with secretions of infected domestic animals. Transmission by ticks to humans is possible but rarely, if ever, occurs. Serological surveys indicate that Q fever is widespread throughout East Asia, to include the Koreas, and infects a wide variety of wild and domestic animals, especially cattle, sheep and goats. Military personnel should avoid exposure to sheep, goats, cattle and other domestic animals and should not sleep or rest in animal shelters. Between 2006 and 2011, there were 65 confirmed cases of Q fever in the ROK (Kwak et al., 2013). The majority of cases were adult males (87.7%) living in urban environments (67.7%). Fifteen of the 65 patients had high-risk occupations, including veterinarian, livestock raiser, slaughterhouse worker, and farmer. Because the disease has a broad spectrum of clinical manifestations, from non-specific febrile illness to neurological disorder, and there have been no known outbreaks in Korea, it is difficult for physicians to diagnose Q fever without increased awareness of this disease (Kwak et al., 2013). Among the 16 provinces and metropolitan cities of Korea, Gyeonggi, Daegu, Chungnam, and Gyeongnam accounted for 61.5% of all cases.

Transmission: The common route of infection is inhalation of contaminated dust, contact with contaminated milk, meat, wool and particularly livestock birthing products. Ticks can transfer the pathogenic agent to other animals. Human-to-human infection is extremely rare. In an investigation of 35 cases in 2008, the most common risk factors were contact with animals (42.9%), visiting animal farms (20%), and participating in animal birthing (17.1%) (Kwak et al., 2013).

Potential Vectors: *Haemaphysalis* spp., other ticks

FLY-BORNE DISEASES

DIARRHEAL DISEASES

See AFPMB Technical Guide 30, Filth Flies - Significance, Surveillance and Control in Contingency Operations.

Filth flies may interfere with military operations through transmission of disease-causing organisms, contamination of food, myiasis (larval infestation of human and animal tissue), and annoyance or distraction from the job at hand. An increasingly persuasive body of evidence suggests that flies play a major role in the spread of enteric disease agents. These pathogens have impacted military operations throughout history, underscoring the need for fly control.

Kobayashi et al. (1999) showed that *Escherichia coli* O157:H7, an extremely virulent serotype of this common bacterium, actively proliferates in the minute spaces of house fly mouthparts, and that this proliferation leads to persistence of the bacteria in fly feces. Based on DNA evidence, they implicated house flies as the source of *E. coli* in an outbreak in a daycare center in Kyushu in western Japan. Fetene and Worku (2009) isolated numerous intestinal pathogens, including *Ascaris lumbricoides, Trichuris trichiura*, hookworm, *Taenia* spp., *Entamoeba* spp., *Cryptosporidium* spp. and *Giardia lamblia*, from gut contents and external surfaces of common filth flies.

Infectious Agents: Over 100 pathogens that can cause human disease are known to contaminate filth flies. The role that filth flies play in actually transmitting pathogens to humans, and to what extent this transmission leads to disease depends on the pathogen and associated environmental factors. In some instances, transmission by flies may be significant, while in other instances it is nonexistent. Just because a pathogen is recovered from a fly does not mean that successful transmission is possible. Pathogens include bacteria (*Aeromonas* spp., *Campylobacter* spp., *Escherichia coli*, *Salmonella* spp., *Shigella* spp., *Vibrio parahaemolyticus*, *Yersinia enterocolitica*) and protozoa (*Cryptosporidium* spp., *Entamoeba histolytica*, *Giardia lamblia*). Rotavirus and enteric adenoviruses have been reported as causes of gastroenteritis among indigenous children and newly deployed US forces.

Epidemiology: Filth flies have been implicated in the direct and indirect mechanical transmission of a number of pathogens responsible for human diseases, especially those causing diarrheal illness. Mechanical transmission is the transfer of pathogens from one location to another, usually passively or unintentionally. Thus, mechanical transmission of disease organisms is facilitated by adult filth flies' habit of walking and feeding on materials that tend to be contaminated, then doing the same on food to be consumed by humans. Regurgitating and defecating while feeding also increase the potential for transmission of pathogens by flies (AFPMB Technical Guide 30). In a study of 10,000 patients hospitalized for diarrhea in 2004-2006 in the Republic of Korea, protozoal, viral, and bacterial pathogens were detected at rates of 1.3%, 17.6%, and 18.0%, respectively (Cheun et al., 2010).

Transmission: Enteric diseases are usually acquired from contaminated food and water. Filth flies may serve as mechanical vectors. Sanitation and hygiene, including fly control, exclusion and source reduction should be strongly emphasized.

Primary Vectors: *Musca domestica*, *Musca sorbens*, *Fannia canicularis*, and other human-associated flies. A list of the flies ecologically associated with humans in Korea appears in

Appendix D.

Vector Bionomics: Larvae develop in excrement, garbage and latrines, feeding on waste materials and associated microorganisms. Though capable of flying considerable distances, most filth fly species disperse no more than a few kilometers from their breeding sites, so illness from fly-borne enteric pathogens is frequently focal. Filth flies are extremely prolific, and populations decimated by control measures or weather variables can quickly recover their former numbers.

MITE-BORNE DISEASES

SCRUB TYPHUS (Chigger-borne Rickettsiosis, Tsutsugamushi Disease)

(Infectious Disease Risk Assessment Database - DPRK, https://www.ncmi.detrick.army.mil/product/idra_db.php?co=PRK)

(Infectious Disease Risk Assessment Database - ROK, https://www.ncmi.detrick.army.mil/product/idra_db.php?co=KOR)

Infectious Agent: Bacterium, *Orientia tsutsugamushi*

Epidemiology: Scrub typhus is an acute febrile illness caused by the rickettsial bacterium *Orientia tsutsugamushi* (Hayashi) and is transmitted by several species of larval mites (chiggers) belonging to the family Trombiculidae.

In South Korea, scrub typhus is the most common rickettsial disease, with case numbers increasing more than three-fold during the period 2001-2012. The number of cases grew sharply from 2,637 in 2001 to over 8,300 in 2012 (Rhee, 2013). It is known that the pathogenicity of *O. tsutsugamushi* for humans varies depending on the serotype of the pathogen (Kelly et al., 2002). In Korea, the Karp, Gilliam, Boryong, and Yonchon serotypes have been identified. Karp and Gilliam types are found primarily in central Korea, whereas Boryong is predominant in the south. In a study of wild rodents and chiggers collected from 31 locations throughout the ROK to determine the geographical distribution of *O. tsutsugamushi* serotypes, the Boryong strain was predominant (80.1%) throughout the country, including Cheju-do, whereas the Karp strain was found only in central Korea (Ree et al., 2001).

Scrub typhus was first reported in Korea when eight United Nations Soldiers were diagnosed with it during the Korean War. Prior to the Korean War, scrub typhus was not known to occur among the Korean population, although unconfirmed reports based on symptoms of scrub typhus, e.g., fever, chills, headache and rash, had been observed during the late autumn to early winter for many years. After the Korean War, scrub typhus cases were reported in relatively low numbers in the ROK population and the disease was not made reportable in the ROK until 1994.

Although scrub typhus has historically been considered a disease that mostly affects women and

the elderly in agricultural areas, it has begun to spread across the ROK and across different age groups. The proportion of cases identified in farmers decreased from 43.3% in 2001 to 25.0% in 2009, while cases in urban areas increased from 20.0% in 2002 to 26.9% in 2009 (Kim et al., 2010d). Of 4,254 cases reported in South Korea during 2009, 1,028 were reported from urban areas and 3,226 from rural areas (Kim et al., 2010d). The most common risk factor for infection in urban areas is outdoor activity, including participation in government run public work projects, such as maintenance of hiking trails, deforestation, and cutting grass.

Most human cases occur in October and November. The southwestern and middle-western parts of Korea, such as Jeollanam-do, Jeollabuk-do, and Chungcheongnam-do, have higher prevalence of the disease than other areas (Kim et al., 2010c; Lee et al., 2012). Figure 13 shows a scrub typhus incidence map for the ROK.

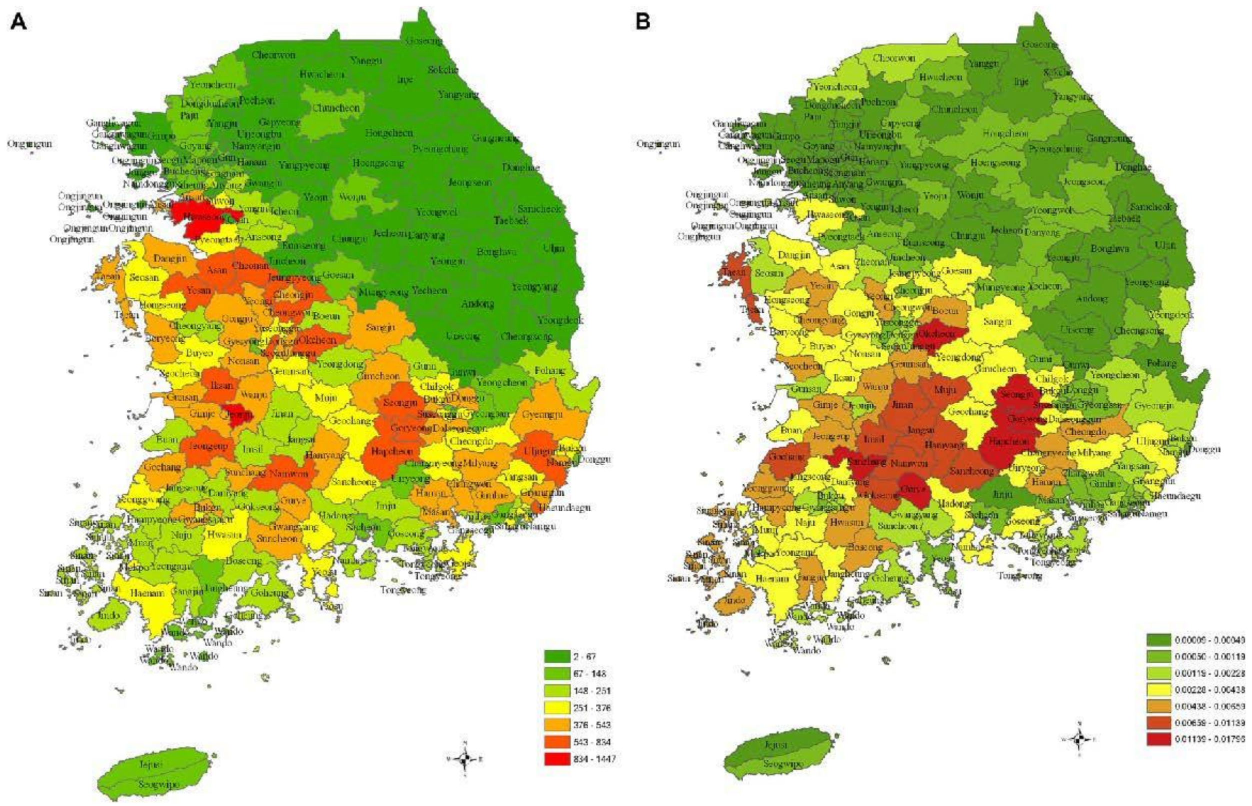

Figure 13. (A) Incidence map by districts; (B) incidence rate map by districts per capita (Jin et al., 2013).

While there have been few confirmed scrub typhus cases among US personnel (one case each in 1995 and 2003), it remains a serious health threat, as it can rapidly incapacitate large numbers of persons and degrade military operations (Kim et al., 2010c). Investigations to identify transmission rates of scrub typhus in US soldiers deployed to the ROK were initiated as a result

of a comprehensive rodent surveillance program at field training sites supported by funding through the Armed Forces Health Surveillance Center (AFHSC), Division of Global Emerging Infections Surveillance and Response System (GEIS), and the National Center for Medical Intelligence (NCMI) (Lee et al., 2009b; Sames et al., 2010; Kim et al., 2010c). These investigations identified scrub typhus infection rates in rodent populations ranging from 11.1% to 100%. In another study, data indicated approximately 0.2% of US personnel seroconverted for scrub typhus while deployed to the ROK. In addition, bites by chiggers in Korea, unlike the Americas, usually do not elicit an "itchy" response; thus, personnel do not realize they have been bitten. These data demonstrate the value of conducting vector and reservoir surveillance to determine the threat of known, reemerging and unknown infectious disease threats. Assessment of the risk of scrub typhus to the US Forces Korea (USFK) population is difficult, as few cases are diagnosed in the USFK population compared to the disease presence in the Korean population. It is not fully understood why there are so few post-deployment positive sera for scrub typhus and suspected cases among USFK personnel, but it may be related to using diagnostic assays with low sensitivity, lack of provider awareness and education on emerging diseases in the ROK, and perhaps presumptive treatment with doxycycline with no serology follow-up to determine the cause of illness. Even though scrub typhus appears to be having a low impact on current USFK populations, an outbreak of hostilities or a natural disaster requiring humanitarian interventions could quickly change this status, especially in light of the relatively high number of cases observed in the Korean population.

Recently, Chung et al. (2012) demonstrated that *O. tsutsugamushi* can persist in the body after antibiotic treatment and apparent recovery, causing a chronic latent infection. They were able to isolate *O. tsutsugamushi* from six patients from 1 to 18 months following typical antibiotic therapy.

Transmission: *O. tsutsugamushi* is transmitted to zoonotic hosts and man (the latter being an incidental host) by the bite of infected larval trombiculid mites (chiggers) in the subgenus *Leptotrombidium*. More recently, two other genera of chiggers, *Neotrombicula* and *Eushoengastia*, have been found infected with *O. tsutsugamushi* in the ROK. Maintenance of *O. tsutsugamushi* is through transovarial transmission among "susceptible" populations of chigger vectors. Such transmission appears to be essential to the maintenance of the infection in nature; thus, the mite serves as both the vector and the reservoir.

Potential Vectors: Although a total of 41 species of chigger mites have been reported from the ROK, only a small number have been associated with scrub typhus. An updated list of Korean chiggers is contained in Appendix E.

Likely vectors include *Leptotrombidium scutellare*, *L. pallidum*, *L. orientale*, *L. palpale* and *L. zetum*. *Orientia tsutsugamushi* has been detected in a number of other chigger species; however, further studies are needed to confirm what role they play in disease transmission (Figure 14).

A number of surveillance studies have been conducted in the ROK to monitor vector and small mammal populations and scrub typhus infection rates. *Orientia tsutsugamushi* was detected in 22/830 chiggers of six species collected from wild rodents at 9 localities in the ROK, with an overall infection rate of 2.7% (Lee et al., 2011b). The infection rate was highest for *L. palpale* (5.3%), followed by *Neotrombicula japonica* (4.3%), *L. scutellare* (3.7%), *L. orientale* (3.6%), *Eushoengastia koreaensis* (1.9%), and *L. pallidum* (1.5%).

Figure 14. Larval *Leptotrombidium* chigger (Armed Forces Research Institute of Medical Sciences)

Research by O'Guinn et al. (2010) showed scrub typhus seropositive rates in *Apodemus agrarius* at Firing Points 10 and 60, located in Yonchon County near the DMZ, averaging 61% over a five-year period. Likewise, in a rodent-borne disease surveillance program conducted at eight US and ROK operated military training sites near the DMZ, northern Gyeonggi-do Province, antibodies reactive to *O. tsutsugamushi* were detected in 6 of 8 small mammal species. In *A. agrarius*, which accounted for over 87% of all animals collected, scrub typhus seropositive rates ranged from 26.9% in August to over 54% in November, December and March (Kim et al., 2010c). Although rates varied from one locality to another, these data demonstrate the potential for military and public exposure to scrub typhus.

<u>Vector Bionomics</u>: Mite eggs are laid singly and loosely in low, humid grassy areas. About 1-5 eggs are laid daily for 6-12 weeks. The females then pause for 2-6 months depending on climate before resuming oviposition. The egg stage lasts 5-7 days, with the larva developing inside the cracked egg for another 5-7 days. The 6-legged larva then emerges and remains in the immediate area until it encounters a host (usually any rodent in the family Muridae). Chiggers feed on serum exudate, rarely imbibing blood, for 2-3 days. Engorged larvae disengage, drop off and enter a pupa-like stage (nymphochrysalis) for 7-10 days. An eight-legged velvety nymph emerges, and within two weeks, another pupa-like stage (imagochrysalis) occurs, which lasts 12-15 days. Adults emerge and may live up to 15 months. Nymphs and adults are free-living and appear to feed on insect eggs and small, soft, inactive soil invertebrates. Since chigger mites can

survive during the winter period and are believed to lay eggs mainly in the summer in Korea, the survival of chigger mites during winter can influence the incidence of scrub typhus the following year (Noh et al., 2013). In a given area, mite populations are often found in highly localized aggregations or "mite islands," resulting in hit-or-miss human exposure. Annual mean temperatures can also limit vector distribution. *Leptotrombidium scutellare* was found almost exclusively in areas where the mean annual temperature was above 10°C (Ree et al., 1997). Because of climate change, *L. scutellare* could expand its distribution to middle or northern parts of the Korean peninsula, and its abundance and population peak could change.

Surveillance of small mammals and associated zoonotic diseases has been conducted in military-restricted areas near the DMZ where ROK and US military personnel are deployed and/or train. The presence of vectors of *O. tsutsugamushi*, relatively high scrub typhus seroprevalence rates among rodents, and transitory vegetation in disturbed environments, which are characteristic of military training sites located near the DMZ, place military personnel training in these habitats at risk for scrub typhus. Cantonment sites are often established adjacent to tall grasses and forested margins, while training activities place military personnel at risk in chigger-infested habitats along roadsides, firing positions, or other grassy areas.

In a study conducted in nine localities across the ROK in 2005, *L. pallidum* was found to be the most widely distributed chigger species and was especially prevalent in the northern part of the ROK. In Gyeonggi and Gangwon Provinces, *L. pallidum* was the predominant species, accounting for >50% of all chiggers collected. In the southern part of the ROK, *L. scutellare* was the predominant species, accounting for >50% of the chigger population, whereas *L. pallidum* occurred in low numbers (Lee et al., 2011b).

FLEA-BORNE DISEASES

Fleas are vectors of zoonotic pathogens of public health importance. These include plague, murine typhus, and other flea-borne rickettsial pathogens (Parola et al., 2005a; Bitam et al., 2010). Flea-borne diseases are emerging or re-emerging throughout the world, their incidence is on the rise, and their distribution and that of their vectors is shifting and expanding. The accidental or intentional introduction of flea-borne diseases poses serious public health risks, especially during military training exercises, natural disasters, or military operations where reservoir hosts (e.g., rodents and insectivores) and associated ectoparasites occur in high densities or hosts are displaced, leaving the hungry ectoparasites. Fleas are very mobile and will often abandon their natural host(s), especially after death of the host; such fleas can readily utilize other hosts, including humans (Azad et al., 1997).

PLAGUE

Infectious Agent: *Yersinia pestis*

Epidemiology: Presently, the threat of plague to military operations in South Korea is low, but persistent enzootic foci can trigger the recurrence of epidemics when war or natural disasters disrupt general sanitation and health services. Plague is a zoonotic bacterial disease involving rodents and their fleas, some species of which transmit the infection to man and other animals (Armed Forces Pest Management Board, 2002). The most frequent route of transmission to humans is by the bite of infected fleas, but plague may also be acquired by handling tissues of infected animals or humans, and by person-to-person transmission of pneumonic plague. The infectious agent causes fever, chills, myalgia, nausea, sore throat and headache. Bacteria accumulate and swelling develops in the lymph nodes closest to the infected bite. Since most fleabites occur on the lower extremities, the nodes in the inguinal region are involved in 90% of cases. The term bubonic plague is derived from the swollen and tender buboes that develop. Plague is most easily treated with antibiotics in the early stages of the disease. Untreated bubonic plague has a fatality rate of 50%. Infection may progress to septicemic plague, with dissemination of the bacteria in the bloodstream to diverse parts of the body. Secondary involvement of the lungs results in pneumonia. Pneumonic plague is of special medical significance since respiratory aerosols may serve as a source of person-to-person transmission. This can result in devastating epidemics in densely populated areas. Pneumonic and septicemic plague are invariably fatal when untreated but respond to early antibiotic therapy. Plague is often misdiagnosed, especially when travelers or military personnel develop symptoms after returning from an enzootic area. To ensure proper diagnosis, medical personnel should be aware of areas where the disease is enzootic.

Plague is maintained in nature among wild rodents and their fleas (Armed Forces Pest Management Board, 2002). This cycle is termed zoonotic, sylvatic, campestral, rural, or wild plague, and can be very complex, involving many rodent and flea species. Little is known about the biology of most wild rodent fleas. Worldwide, over 220 species of rodents have been shown to harbor *Y. pestis*. In addition, the camel and goat are susceptible to infection with plague bacteria and may play a significant role in the dissemination of human plague when infected animals are butchered for human consumption.

The most recent plague pandemic originated at the close of the 19th century in northern China and spread to other continents by way of rats on steamships. During World War II, plague presented a significant threat to US military forces in the Orient, but none contracted the disease (Armed Forces Pest Management Board, 2002). This was attributed to effective rodent control, DDT for flea control, chemoprophylaxis, and the use of preliminary plague vaccines. Severe ecological disturbances and dislocations of human populations during the Vietnam War led to outbreaks of plague, primarily in native populations.

Vector Transmission: The most frequent route of plague transmission to humans is by the bite of infected fleas. Crushed infected fleas and flea feces inoculated into skin abrasions or mucous membranes can also cause infection. Fleas often exhibit a host preference, but species of medical importance readily pass from one host to another (Armed Forces Pest Management Board, 2002). A lack of absolute host specificity increases the potential for infection and transmission of pathogens. Not all flea species are competent vectors. The vector competence of the Oriental rat flea is attributed to enzymes produced by the plague bacilli that cause blood to coagulate in the flea's digestive tract. The flea attempts to clear the blockage in its digestive tract by repeated efforts to feed. In the process, plague bacilli are inoculated into the host. Fleas may remain infective for months when temperature and humidity are favorable. *Xenopsylla cheopis* may require 2 to 3 weeks after an infective bloodmeal before it can transmit plague bacilli.

Most cases in military personnel would likely occur as a result of intrusion into areas where the zoonotic cycle is taking place during or following an epizootic of plague in wild rodents (Armed Forces Pest Management Board, 2002). In addition, domestic cats and dogs may carry infected rodent fleas into buildings or tents. Cats may occasionally transmit infection by their bites or scratches, or by aerosol when they have pneumonic plague. Troops should not be allowed to adopt cats or dogs as pets during military operations. The entry of wild rodents or their infected fleas into human habitations can initiate an epizootic among commensal rodents, primarily *Rattus* spp., which are highly susceptible to infection. Close association of humans with large populations of infected commensal rodents can result in an urban cycle of plague. A similar cycle can occur in military cantonments experiencing large infestations of commensal rodents.

Primary Vector: The most important vector of urban plague is the Oriental rat flea, *Xenopsylla cheopis*; the human flea, *Pulex irritans*, is a secondary vector in East Asia (Armed Forces Pest Management Board, 2002).

Vector Bionomics: *Xenopsylla cheopis* occurs mostly in urban areas, in association with its rodent hosts (Armed Forces Pest Management Board, 2002). However, it may occur sporadically in villages when rats are present. Adult fleas feed exclusively on blood and utilize blood protein for egg production. After feeding on a rodent, the female Oriental rat flea lays several eggs (2 to 15). Hundreds of eggs may be laid during the entire life span. Oviposition most often occurs on the hairs of the host, but the eggs drop off and hatch in the nest or its environs. In locally humid environments, such as rodent burrows, eggs may hatch in as little as 2 days. Larvae grow rapidly when temperature and relative humidity are above 25^{o}C and 70%, respectively; they live in the nest, feeding on dried blood, dander, and other organic materials. The larval stages can be completed in as little as 14 days (at 30 to 32^{o}C), or as many as 200 days when temperatures drop below 15^{o}C or when nutrition is inadequate. Mature larvae pupate in cocoons, loosely attached to nesting material. Adult emergence may occur in as little as 7 days or as long as a year and is stimulated by carbon dioxide or host activity near the cocoon. Adult fleas normally await the approach of a host rather than actively search for one. Fleas feed on

humans when people and rodents live close together, but man is not a preferred host. However, if rat populations decline suddenly due to disease or rat control programs, these fleas readily switch to feeding on humans. The life span of adult *X. cheopis* is relatively short compared to that of other flea species, often less than 40 days. Flea populations increase rapidly during periods of warm, moist weather.

Pulex irritans, commonly termed the human flea, occurs mainly among lower socioeconomic groups (Armed Forces Pest Management Board, 2002). It is a secondary vector of plague in East Asia and is more widely distributed in China than in Mongolia. The life cycle of the human flea is similar to that of the Oriental rat flea. Despite its common name, *P. irritans* has a low to moderate preference for humans and is more likely to feed on a variety of rodents, including mice, susliks, voles, pikas, and gerbils, maintaining the enzootic plague cycle among these hosts. Where swine occur, the human flea prefers this host to humans. Domestic animals such as dogs also serve as hosts, but in the absence of preferred hosts, this flea readily feeds on humans and is frequently found in human habitations. *Pulex irritans* can live over one year on its preferred hosts. It can survive unfed for several months.

Vector surveillance and suppression depend upon the species of flea, the host, the ecological situation, and the objective of the investigation (Armed Forces Pest Management Board, 2002). Fleas can be collected from hosts or their habitat. The relationship of host density to flea density should be considered in assessing flea populations. It has been common practice for years to use a flea index (average number of fleas per host), especially in studies of rodent fleas. For *X. cheopis*, a flea index > 1.0 flea per host is considered high. The flea index has many limitations, since only adults are considered and then only while they are on the host. Fleas are recovered by combing or brushing the host or by running a stream of carbon dioxide through the fur while holding the host over a white surface. Flea abundance in the environment can also be determined by counting the number of fleas landing or crawling in 1 minute on the lower parts of the trouser legs and boots of the observer. The trouser legs should be tucked into the socks to prevent bites. Flea populations can also be estimated by placing a white cloth on the floor in buildings or on the ground in rodent habitat and counting the fleas that jump onto the cloth. Various flea traps have been devised. Some use light or carbon dioxide as an attractant or stimulant. Sifting and flotation of rodent nesting materials or of dust and debris from infested buildings are also effective methods of collecting fleas from the environment. Serologies of wild carnivores are sensitive indicators of enzootic plague. Fleas and tissues from suspected reservoirs or humans may be submitted for plague analysis to the Centers for Disease Control and Prevention, National Center for Infectious Diseases, Division of Vector-borne Infectious Diseases, P.O. Box 2087, Foothills Campus, Fort Collins, Colorado 80522. Blood samples can be collected on Nobuto paper strips, dried and submitted to a laboratory for testing.

Control of enzootic plague over large areas is not feasible (Armed Forces Pest Management Board, 2002). Control efforts should be limited to foci adjacent to urban areas, military encampments, or other areas frequented by military personnel. If possible, cantonment sites

should not be located in wild rodent habitats. Fleas quickly leave the bodies of dead or dying rodents in search of new hosts. Consequently, flea control must always precede or coincide with rodent control operations. Application of insecticidal dusts to rodent burrows is effective in reducing flea populations, but it is very labor intensive. Fleas can be controlled by attracting infested rodents to bait stations. The stations may incorporate an insecticidal dust that rodents pick up while feeding or a rodent bait containing a systemic insecticide that fleas ingest when taking a bloodmeal. However, baiting with systemic formulations may pose environmental risks.

Urban plague control requires that rodent runs, harborages and burrows be dusted with an insecticide labeled for flea control and known to be effective against local fleas (Armed Forces Pest Management Board, 2002). Insecticide bait stations can also be used. Rat populations should be suppressed by well-planned and intensive campaigns of poisoning and concurrent measures to reduce rat harborages and food sources. Buildings should be rat-proofed to the extent possible to prevent rats from gaining entry.   Insecticides recommended for flea control are listed in TIM 24, Contingency Pest Management Guide.

Military personnel, especially those involved in rodent control, should use the personal protective measures described in the Armed Forces Pest Management Board's Technical Guide 36, *Personal Protective Techniques Against Insects and Other Arthropods of Military Significance* (Armed Forces Pest Management Board, 2009). The efficacy of plague vaccine in humans has not been demonstrated in a controlled trial, so vaccination should not be relied upon as the sole preventive measure (Armed Forces Pest Management Board, 2002).

MURINE TYPHUS

Infectious Agent: *Rickettsia typhi*

Epidemiology: Murine typhus is uncommon in the ROK. Historically, sporadic outbreaks have occurred, especially around seaports and in warehouse areas. Three cases of murine typhus were confirmed in 1961, and the pathogen was isolated from 2 patients in 1987 (Kim et al., 1988). While no outbreaks have been reported, >200 cases of murine typhus are presumed to occur annually in the ROK (Choi et al., 2005). The basic transmission cycle of infection is rodent-flea-rodent and, accidentally, rodent-flea-human. Conditions supporting large populations of rodents, such as poor sanitation, allow for endemicity of disease. *Rickettsia typhi* is usually characterized as an urban disease involving the Oriental rat flea, *Xenopsylla cheopis*, or the cat flea, *Ctenocephalides felis*, but these are replaced by other vectors and zoonotic hosts in rural environments. Murine typhus seropositive rates among *A. agrarius*, the most commonly collected rodent in rural areas, are generally less than 5% (O'Guinn et al., 2010; Payne et al., 2009). However, at Twin Bridges Training Area, approximately 15% of the *A. agrarius* were seropositive for *R. typhi* (Sames et al., 2010). Humans are incidental hosts, and military personnel are especially at risk of becoming infected during training exercises in disturbed

rodent-infested habitats and in urban areas, especially when rodents are displaced or killed, leaving the fleas to seek blood meals from alternate hosts.

Vector Transmission: Murine typhus is not transmitted by flea bite. Infection occurs by contamination of abraded skin or mucous membranes (e.g., from scratching or rubbing) with feces or crushed bodies of infected fleas. Infection may also be acquired through inhalation of flea feces, which remain infective for years. Transmission of *R. typhi* occurs horizontally, from infected flea to rodent to non-infected flea, and to a lesser degree vertically by transovarial and transstadial transmission (Azad, 1990). Fleas themselves remain infective for over 50 days, probably for life. There is no evidence that *R. typhi* affects the feeding behavior or survival of infected fleas (Azad et al., 1997).

Primary Vector: *Xenopsylla cheopis* (Oriental rat flea). In rural areas, *Ctenophthalmus congeneroides*, *Rhadinopsylla insolita* and *Stenoponia sidimi* are frequently collected and may serve as vectors of murine typhus in Korea, since all have been found positive for *R. typhi* by PCR at training sites near the DMZ (Kim et al., 2010b; Ko et al., 2011).

Vector Bionomics: Female fleas produce 300-400 eggs over a lifetime. They are deposited in scattered clusters in or near the nests of the reservoir hosts. Eggs hatch 2-14 days later and the larvae feed on organic materials, chiefly blood-rich flea fecal material in the nest area. Pupation takes place in a loose silken cocoon to which pieces of debris adhere. Adults may remain in their cocoons if meteorological conditions are unfavorable (e.g., low temperatures, low humidity). The life cycle may be completed in as little as two or three weeks if conditions are optimal. Otherwise, the life cycle is usually about one month. Adult fleas can live for several months under high humidity and moderate temperatures. *Xenopsylla cheopis* is the most numerous and widely distributed rat flea in ROK urban environments, but other species, such as *S.sidimi*, *C. congeneroides* and *R.insolita*, predominate in rural environments (Ko et al., 2011; Kim et al., 2010b; Sames et al., 2010).

FLEA-BORNE SPOTTED FEVER GROUP RICKETTSIOSIS (SFGR) (flea-borne spotted fever, cat flea typhus, or *R. felis* rickettsiosis)

Infectious Agent: *Rickettsia felis*

Epidemiology: *Rickettsia felis* is an emerging pathogen that has been reported from over 25 countries around the globe (Reif and Macaluso, 2009). In addition to cats, *R. felis* has been detected in dogs, rodents, and opossums. The first human case of *R. felis* infection in Asia was reported from Thailand in 2003 (Parola et al., 2005b). Clinical manifestations of *R. felis* infection in humans include fever, rash, headache, myalgia and eschar at the bite site, similar to other rickettsial diseases. The epidemiology of *R. felis* in the ROK is unknown. To date, there have not been any recorded cases of *R. felis* infections among Korean populations. In a

retrospective study of ROK patients with acute febrile illness from 1993 to 1999, PCR was conducted on patient sera to detect and identify SFGR antigens (Choi et al., 2005). *Rickettsia felis* was detected in 3 of 200 samples tested. Ko et al. (2011) reported on results of a rodent-borne disease surveillance program at 20 military installations and training sites, Gyeonggi Province, ROK conducted between 2005 and 2007. They found 6 of 300 flea pools to be positive for *R. felis* for a minimum field infection rate of 1%. *Rickettsia felis*-positive pools were detected in *Ctenophthalmus congeneroides*, *Rhadinopsylla insolita*, and *Stenoponia sidimi* collected from *A. agrarius* at LTA 130 (Yeoncheon), Warrior Base (Paju-si), Twin Bridges training area (Paju- si), and Camp Casey (Dongducheon-si), Gyeonggi Province.

Vector Transmission: Maintenance of *R. felis* in the environment is most likely a result of stable transmission (transstadial and transovarial transmission) within cat flea populations (Wedincamp and Foil, 2002). Transmission of *R. felis* by other arthropods has not been described. Evidence for *R. felis* transmission from flea to host through salivary secretion is supported by the detection of *R. felis* DNA in the blood of cats exposed to *R. felis*-infected cat fleas (Wedincamp and Foil, 2000).

Potential Vectors: The cat flea, *Ctenocephalides felis*, is currently the only known biological vector of *R. felis*. However, molecular evidence of *R. felis* in other species of fleas as well as in ticks and mites suggests a variety of arthropod hosts (Reif and Macaluso, 2009). In the ROK, *R. felis* has been detected in *S. sidimi*, *C. congeneroides* and *R. insolita.*

LOUSE-BORNE DISEASES

EPIDEMIC TYPHUS

See AFPMB Technical Guide 6, Delousing Procedures for the Control of Louse-borne Disease during Contingency Operations.

Infectious Agent: Bacterium, *Rickettsia prowazeki*

Epidemiology: Prior to 1952, over 1,000 cases per year of epidemic typhus were reported from South Korea, with a 10-15% fatality rate. In 1951, a great epidemic of louse-borne typhus occurred with 32,211 cases and 6,154 deaths. The number of cases dropped suddenly in 1952 after effective control of the epidemic by mass delousing with lindane (Chow, 1973). Cases declined throughout the 1960s and no cases have been reported since 1968. A return to overcrowded and unsanitary conditions, such as might occur during periods of military conflict or natural disasters requiring humanitarian efforts, could lead to a resurgence of epidemic typhus in the region.

Transmission: Epidemic typhus is transmitted by the body louse, *Pediculus humanus humanus*, and the causative pathogen is *Rickettsia prowazeki*, which multiplies in the louse gut. When the

louse gut ruptures, it releases the pathogen into the lumen, where it is voided with feces. Human infections occur when louse feces or body contents are rubbed into skin abrasions when the louse is crushed during scratching. The pathogen may also enter through mucous membranes or inhalation of louse feces. *Rickettsia prowazeki* can remain virulent in dry louse feces for over 60 days. Humans are the only known reservoir of infection. Human survivors of epidemic typhus may remain infective for life. Patients with a mild, chronic form of recrudescent typhus (Brill-Zinsser disease) can serve as reservoirs of infection.

Vector Bionomics: Lice usually inhabit clothing, where their eggs are deposited in the seams. Infestations are usually acquired via direct contact with louse-infested persons or from infested clothing or bedding. Eggs normally hatch in 5-7 days when near the human body, but hatching is reduced or prevented by exposure to temperatures above 38°C (100°F) or below 23°C (75°F). Maturity is reached 2-3 weeks after oviposition. Lice live approximately 30-40 days but they die in 10 days or less if they do not feed and in 8-12 days if they are infected with *Rickettsia*. Temperatures 4-5°F (2.2-2.7°C) (approximately 1.8°F to every 1°C) above that normally found on the host are fatal to adult lice in a few hours, which is the reason lice leave typhus patients with high fevers. Prolonged temperatures at or below 20°C (68°F) also are fatal to adults. Lice may remain infective as long as they are alive.

RELAPSING FEVER

Infectious Agent: Spirochete bacterium, *Borrelia recurrentis*

Epidemiology: No relapsing fever cases have been reported from the ROK since 1962. However, an epidemic occurred in 1951 in association with louse-borne typhus, when over 2,700 cases were reported, with 246 deaths (Chow, 1973). Outbreaks of relapsing fever are associated with squalor, famine and overcrowding, which facilitate the spread of human body lice.

Transmission: Transmission of relapsing fever from person to person is through infected human body lice. Spirochetes are ingested by lice feeding on infected human hosts, and subsequently enter and multiply in the circulatory system of the louse. Lice are highly infective after 6 days and remain so for life (30-40 days). Spirochetes are not transmitted by bite or feces, but they enter the host through skin abrasions or mucus membranes when a louse is scratched or crushed. The present status of *B. recurrentis* in the DPRK is unknown, but it may be present there due to widespread poverty and poor medical care.

Primary Vector: *Pediculus humanus humanus* (body louse, see epidemic typhus)

Potential Vector: *Pediculus humanus capitis* (head louse)

Vector Bionomics: The two louse subspecies are similar, but the head louse is largely confined to the scalp, and it is not normally considered a vector.

OTHER ZOONOTIC DISEASES OF MILITARY IMPORTANCE

VIRAL DISEASES

HEMORRHAGIC FEVER WITH RENAL SYNDROME (HFRS)

See AFPMB Technical Guide 41, Protection from Rodent-borne Diseases with Special Emphasis on Occupational Exposure to Hantavirus, for risk mitigation measures.

(Epidemic Hemorrhagic Fever, Korean Hemorrhagic Fever, Nephropathia Epidemica, Hemorrhagic Nephrosonephritis)

Infectious Agents: Hantaviruses (Bunyaviridae)

Epidemiology: Hantaviruses, the causative agent of Hemorrhagic Fever with Renal Syndrome (HFRS), are transmitted through aerosols of rodent excreta (urine, feces, and saliva) or by bite of infected rodents. In Korea, there are four rodent-borne hantaviruses: Hantaan (HTNV) (the most severe with 5-10% mortality with the best of supportive care), Seoul (SEOV) (usually mild to moderate with <1% mortality), Soochong (SOOV), and Muju (MUJV) viruses (Baek et al., 2006; Song et al., 2007). Little information is available on the severity of SOOV and MUJV because they were only recently identified and epidemiological investigations of patients are infrequently done. In addition, Imjin virus (IMJV), a soricomorph (shrew-borne) hantavirus of unknown etiology, does not cross-react serologically with the rodent-borne hantaviruses (Song et al., 2009a). Currently, there is no strong evidence that Imjin virus causes human disease. There have been approximately 400 cases of hantavirus reported annually over the past several years by the Korea Center for Disease Control and Prevention (Figure 15). The higher number of cases subsequent to 2003 is most likely due primarily to improved reporting. Approximately 70% of the reported cases are Hantaan virus, while 30% are Seoul, Muju and Soochong viruses (Noh et al., 2006).

HFRS was first diagnosed as Korean Hemorrhagic Fever, or KHF, in 1951 in UN soldiers during the Korean War, and was a major cause of morbidity and mortality between 1951 and 1954. During the Korean War, nearly 2,500 hantavirus cases were documented in US forces, with a 5.5% case fatality rate (Department of the Army, 1956); most cases occurred north of Seoul and a large majority occurred north of the 38th parallel (Gauld and Craig, 1954). Currently, HFRS risks are low near the southern tip of the peninsula and increase toward the DMZ. Sporadic cases (0-14) have been reported over the past two decades in US forces deployed to the ROK (Figure 16), with the highest number of cases (14 cases with 2 fatalities) in 1986 (Pon et al.,1990). From 2006 to 2010, there were no reported HFRS cases among US military personnel, likely as a result of proactive preventive medicine investigations that warned commanders not to use selected training sites during the high-risk periods.

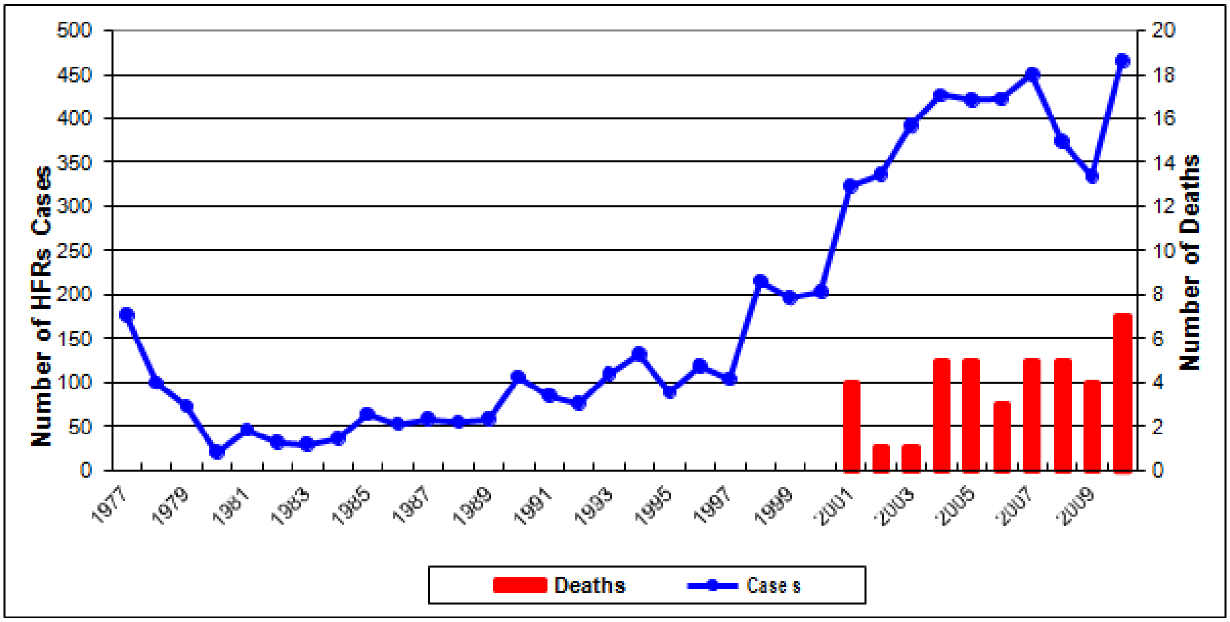

Figure 15. Number of reported hantavirus cases, 1977-2010.

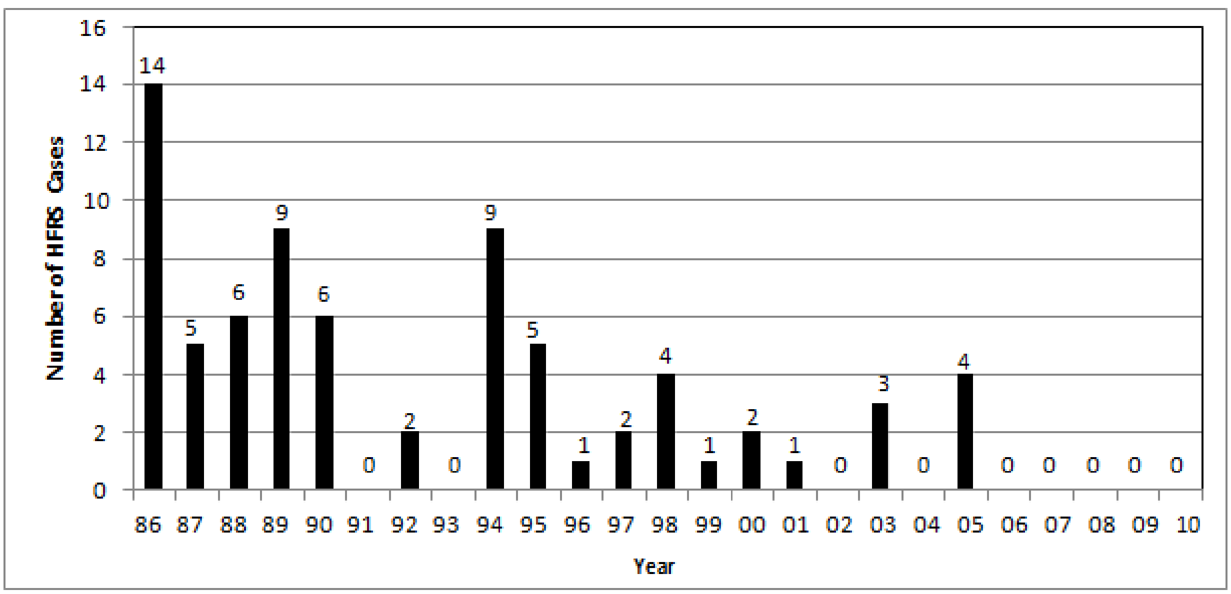

Figure 16. Number of hantavirus cases reported among US service members, 1986-2010.

Infection of laboratory personnel working with infected rodents has occurred, and personnel working in the field collecting small mammals must use precautions when handling rodents (Mills et al., 1995). The incubation period for HFRS is generally 2 to 3 weeks but may be as short as 4 days or as long as 42 days (Lee, 1989). HFRS manifests as flu-like symptoms (fever, headache, backache, malaise, muscle aches) that often result in delayed diagnoses. In several

cases, symptoms have mimicked those of appendicitis, resulting in the appendix of HFRS patients being removed. Proteinuria is a discriminator for evaluating patients for HFRS. In later stages, kidney involvement may lead to renal shutdown and hemorrhagic manifestations, and if the patient recovers during this phase, the elimination of large amounts of urine may lead to shock (electrolyte imbalance) and death. HFRS risks are highest subsequent to increases in young, naïve (i.e., uninfected) rodents during March-April and August-September. Thus, moderate risks occur from April to June and high risks are present during late August through early November.

Transmission: Rodent to human transmission of hantaviruses occurs through the aerosolization and inhalation of rodent excreta (feces, urine, and saliva) or by bite of infected rodents. No person-to-person transmission has been documented. While shedding of HTNV continues throughout the life of the rodent, it is thought to be greater in acute infections compared to chronic infections. Maintenance of the virus in rodent populations is believed to be primarily through horizontal transmission during the fall mating season, when there is a large influx of young naïve rodents competing for limited winter habitats, and by indirect transmission (e.g., contaminated soil). Data also suggest that the large infusion of young naïve rodents during the fall results in higher numbers of acute infections with higher viral shedding, increasing the potential for HTNV transmission (Sames et al., 2009b).

Ryou et al. (2011) reported on the prevalence of hantavirus infections in wild rodents collected during 2007 from five counties in five ROK provinces: Hwaseong County in Gyeonggi Province; Yesan, Chungcheognam Province; Hapcheon, Gyeongsangnam Province; Gurye, Jeollanam Province; and Jeonju, Jeollabuk Province. *Apodemus agrarius* was the most frequently captured rodent at all sites, accounting for 98.2% of the 752 animals examined. Rodent antibody prevalence in the five provinces ranged from a low of 4% (2/56) in Jeonju to 28.6% (52/182) in Hwaseong. Human HTNV virus cases recorded during the study period were also highest in Hwaseong. Seasonally, there were two peaks in antibody prevalence in striped field mice, one in April and the other from September to December. Most cases of HFRS in South Korea occurred during the second peak.

After three US service members contracted HFRS at Three Bridges training area in late October and early November 2005, a 3-year study was conducted to examine the dynamics of HFRS in the small mammal population. The overall HTNV antibody positive rate in *A. agrarius* over three years was 14.5% (122/842). However, during December 2005, following the diagnosis of three soldiers with HFRS, the overall antibody-positive rate was 34.4% (22/64). In studies conducted since 2001, HTNV antibody-positive rates were usually >25% in rodent surveys at training sites where transmission occurred, and were usually <15% when no transmission was detected (Sames et al., 2009b). Because HTNV virus varies geographically, sequencing specific gene fragments can be used to compare a patient's virus with HTNV recovered from rodents collected in areas where patients may have been exposed, thereby determining the most likely site of infection (Song et al., 2009b). Virus isolated from the US soldiers in 2005 was compared

to virus recovered from trapped rodents to identify their likely exposure site. From this information, it was hypothesized that exposure likely occurred at three different locations within the Three Bridges Training Area and resulted from contact with the virus through the back-blast from artillery or dust from riding in open cabs of vehicles (Klein et al., 2012).

HFRS cases in urban areas (SEOV) are associated with commensal rats as reservoir hosts. Sachar et al. (2003) reported the first case of SEOV virus infection in an active duty US Soldier stationed at Yongsan Garrison (Seoul, Korea) who had no field exposure. Kim et al. (2007c) described a rodent survey conducted from 2001 through 2005 at Yongsan Garrison, where a total of 1,750 rodents representing three species and two genera were collected, with *Rattus norvegicus* being the predominant species. Of 395 *R. norvegicus* tested, 38 (9.6%) were found to be infected with SEOV. *Rattus norvegicus* should be considered an important reservoir of SEOV in urban environments, placing US military personnel, civilians, and family members at risk for disease (Figure 17).

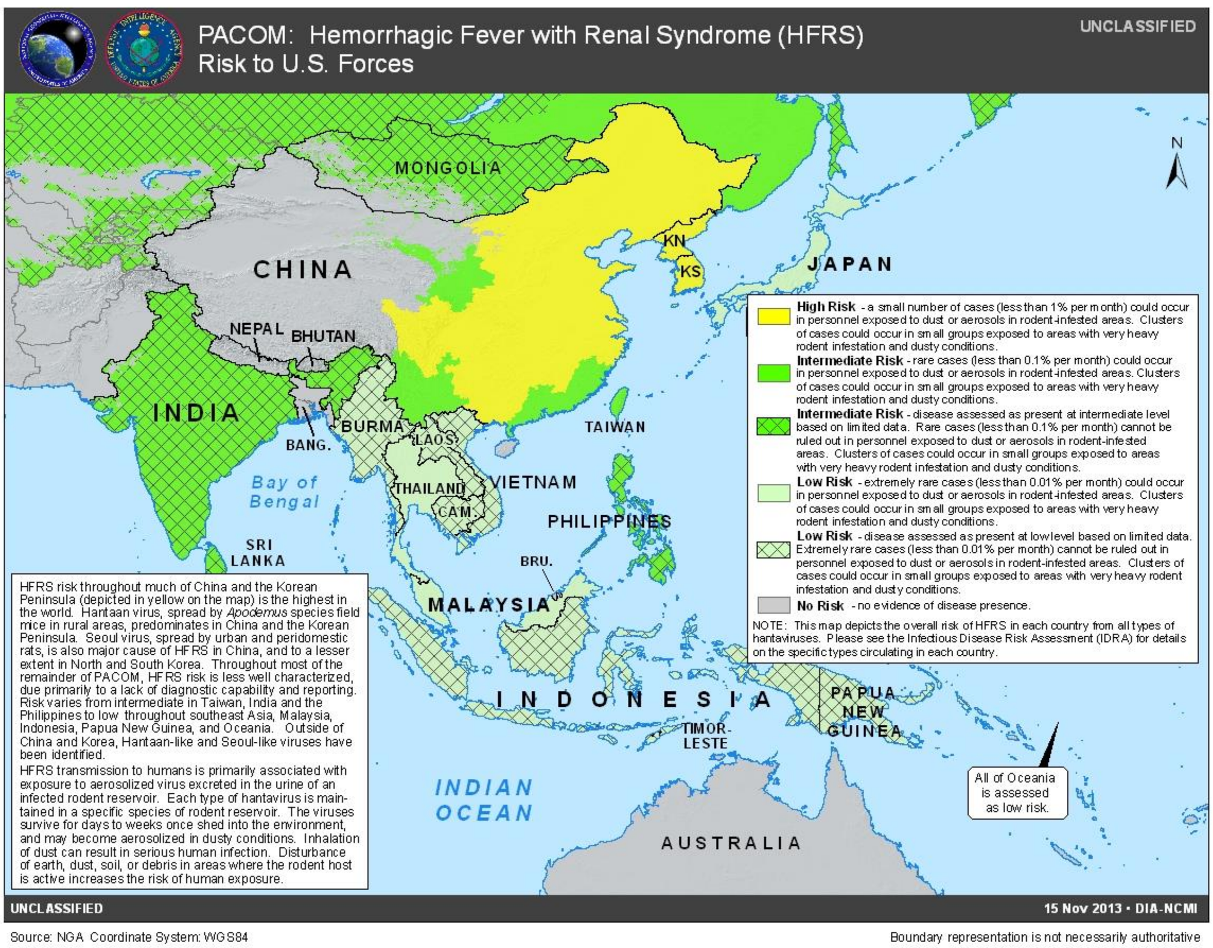

Figure 17. HFRS risk map of Asia.

Bionomics: The four rodent-borne hantaviruses and one soricomorph (shrew-borne) hantavirus found in the ROK are listed in Table 3. *Apodemus agrarius* (Figure 18), the striped field mouse, serves as the reservoir for HTNV, the most severe and most common of the hantaviruses in South Korea. *Rattus norvegicus* and *R. rattus*, the Norway and roof rats, respectively, are the reservoirs for SEOV, which accounts for 20% of documented cases. The rodent reservoirs for SOOV and MUJV are *Apodemus peninsulae* (Korean field mouse) and *Myodes regulus* (royal vole). These two viruses account for less than 10% of the reported cases and little is known about the severity and epidemiology of these viruses since they were only recently identified. The reservoir for IMJV is *Crocidura lasiura* (Ussuri shrew).

Rodent-borne disease surveillance is a necessary component for any preventive medicine program to adequately monitor the relative disease risks for US forces training in HTNV high-endemic areas (O'Guinn et al., 2008).

Table 3. Hantavirus host habitats and relative mortality of hantaviruses.

Disease	Pathogen	Mortality	Reservoir Host	Habitat	Links
Hemorrhagic Fever with Renal Syndrome	Hantaan virus	5-10%	*Apodemus agrarius* (striped field mouse)	Tall grasses and herbaceous vegetation, especially along banks	Lee et al., 1978
	Seoul virus	<1%	*Rattus norvegicus* (Norway rat) & *Rattus rattus* (roof rat)	Urban environments, buildings, tall grasses and vegetation	Lee et al., 1978
	Soochong virus	Unknown	*Apodemus peninsulae* (Korean field mouse)	Tall grasses and herbaceous and crawling vegetation, especially along banks	Baek et al., 2006
	Muju virus	Unknown	*Myodes regulus* (royal vole)	Tall grasses and herbaceous and crawling vegetation	Song et al., 2007
	Imjin virus	Unknown	*Crocidura lasiura* (Ussuri shrew)	Abandoned *A. agrarius* burrows, tall grasses and vegetation for ground cover	Song et al., 2009a

Figure 18. *Apodemus agrarius* (illustration courtesy of CDC).

RABIES

Infectious Agent: Rabies virus, family Rhabdoviridae, genus *Lyssavirus*

Epidemiology: Rabies is an important zoonotic disease that results in approximately 55,000 human deaths worldwide annually (World Health Organization, 2014). It is caused by the rabies virus (RV), which produces fatal encephalitis in all mammals, including humans. Rabies transmission primarily occurs through a bite from an infected animal, and the incubation period is dependent upon the bite area. The disease circulates in two epidemiological cycles: an urban cycle involving maintenance of infection predominately in dog populations, and a sylvatic cycle involving wildlife. There is a possibility of spill-over of rabies virus from dogs to wildlife and vice versa (Gongal and Wright, 2011). In South Korea, the raccoon dog (*Nyctereutes procyonoides*) is a principal natural reservoir of rabies virus, but domestic dogs are the predominant animal for transmission (Han et al., 2012). In a molecular epidemiological study performed on 13 Korean virus isolates, Hyun et al. (2005) suggested that rabies viruses in the ROK might have been transmitted from the Far East via the DPRK through raccoon dogs.

The first case of rabies in South Korea was documented in 1907. Between 1907 and 1945, animal rabies cases ranged between 100 and 900 annually. With the initiation of a national rabies control program in 1950 involving mass vaccination of dogs, rabies cases steadily declined, with mean annual case numbers falling to 32 (range 3-91). A significant achievement in rabies control was reached in 1985 when, for the first time since the national control program was launched, no rabies cases were reported. After 8 years with no reported cases, rabies reemerged in 1993, and by 1994 it was detected in cattle, raccoon dogs and domestic dogs. Between 1993 and 2003, the ROK experienced a total of 364 rabies cases in five different animal species and 5 human deaths. All rabies cases, including the five human cases, occurred only in Gyeonggi and Gangwon Provinces (Kim et al., 2006). To prevent human deaths from rabies, a

National Animal Bite Patient Surveillance program was initiated in 2005 to provide post-exposure rabies prophylaxis to animal bite victims. A total of 2,458 animal-related potential rabies exposures in high-risk regions (Figure 19) were reported to Regional Public Health Centers from 2005 to 2009 (Han et al., 2012). Of 2,273 cases involving dog bites, less than 33% of the animals were vaccinated against rabies, which underscores the importance of vaccination in rabies prevention.

Yang et al. (2010) conducted a sero-epidemiological survey for rabies virus in stray and companion dogs from 6 locations in the ROK. Regional seroprevalence ranged from 80% in Cheju to 33% in Gangwon in the high-risk area despite the fact that vaccination of all animals throughout outbreak areas is obligatory and free of charge by the government. Interestingly, strays had an overall higher seroprevalence rate than companion animals (60.1% vs. 49.1%). The low seropositive rates in Gangwon Province suggest seroprevalence could be correlated with rabies outbreaks in that province, and contact between raccoon dogs, as carriers of rabies, and domestic animals could increase the incidence of the disease.

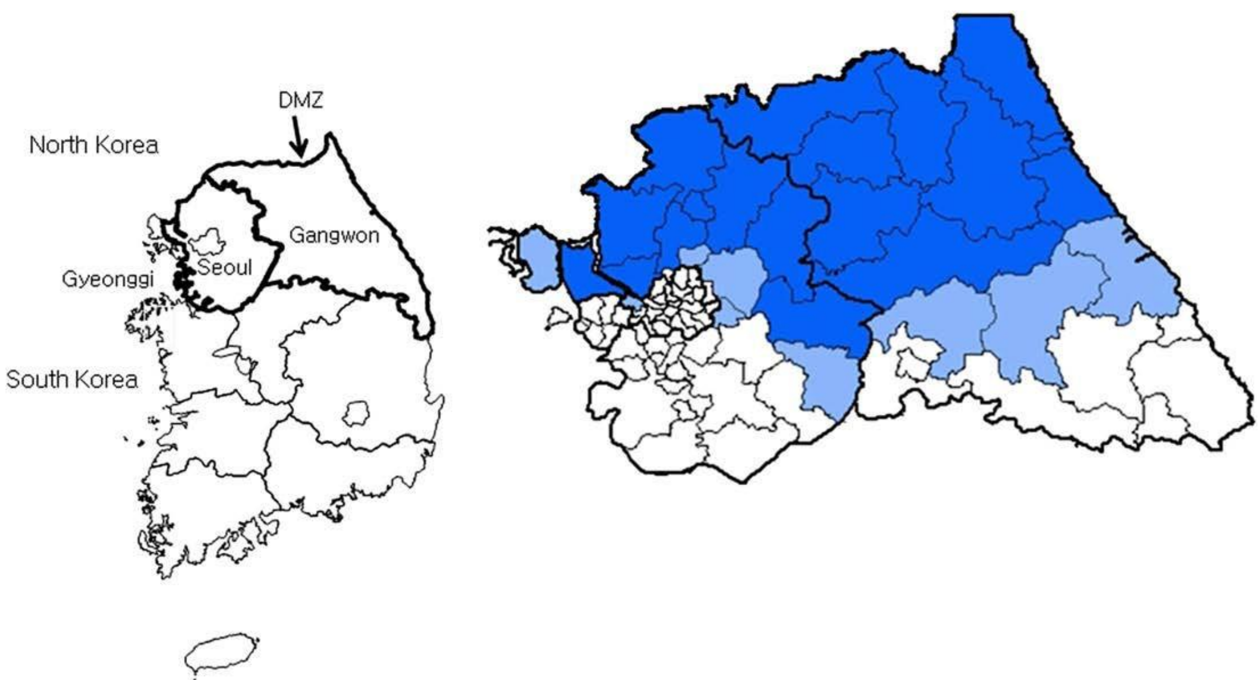

Figure 19. High-risk and suspect-risk regions of human rabies in Korea. The cities or districts where human or animal rabies has occurred since 1993 are designated as high-risk regions (dark blue). The regions are located in the northern part of Gyeonggi and Gangwon Provinces and are surrounded by the Han River, an expressway, the East Sea and the demilitarized zone (Figure from Han et al., 2012).

PARASITIC DISEASES

Infectious Agents: Soil-transmitted helminths, including roundworms (*Ascaris lumbricoides*), whipworm (*Trichuris trichiura*), hookworms (*Ancylostoma duodenale* and *Necator americanus*) and *Trichostrongylus orientalis*. Water-borne parasites, including *Giardia lamblia* and *Cryptosporidium parva.*

Epidemiology: Soil-transmitted helminth infections are among the most common infections worldwide and affect the poorest and most deprived communities. They result from eggs present in human feces that in turn contaminate soil in areas where sanitation is poor. Soil-transmitted helminth infections are widely distributed globally. Intestinal worms produce a broad range of symptoms, including intestinal manifestations (diarrhea, abdominal pain), general malaise and weakness. Hookworms cause chronic intestinal blood loss, which results in anemia.

Until the 1970s, many Koreans had intestinal parasitic infections, mostly soil-transmitted helminths such as *A. lumbricoides*, *T. trichiura*, hookworms (*A. duodenale* and *N. americanus*), and *T. orientalis* (Seo et al., 1969; Kim et al., 1971). Beginning in 1971, a national survey was conducted in the ROK every 5-7 years to monitor the prevalence of intestinal parasitic infections. Data from the first survey in 1971 showed an overall helminth egg positive rate of 84.3% and an accumulated egg positive rate of 147.1%, indicating that people had at least one kind of intestinal parasitic infection. However, during the subsequent 30 years, the ROK moved from an agricultural to an industrial economy with very high economic growth. As a result, a dramatic decrease in the helminth egg-positive rate to 2.4% was achieved by 1997 (Kim et al., 2009a). In particular, *A. lumbriocoides*, a representative intestinal helminth parasite and an index of soil-transmitted helminths, showed a dramatic decrease from 54.9% in the first survey to 0.06% in 1997. Other soil-transmitted helminths also showed dramatic decreases in prevalence: 0.007% for hookworms, 0.04% for *T. trichiura*, and 0% for *T. orientalis.* In the 2004 survey, the total helminth egg positive rate was 3.7% and the estimated number of people infected was 1,780,000. According to the regional analysis, Gyeongsangnam-do showed the highest prevalence of 16.3%, followed by 13.3% in Daejeon, 10.9% in Chungcheongnam-do, and 8.6% in Jeollanam-do. Hookworms, *T. orientalis*, and tapeworms were not found, and the roundworm and several other parasites showed very low positive rates. These results, together with previous surveys, clearly indicate that there has been successful control of soil-transmitted helminths in Korea (Hong et al., 2006).

Giardia lamblia is an intestinal flagellate that infects a wide range of vertebrate hosts, including domestic and wild mammals and humans. *Giardia lamblia* has a simple 2-stage life cycle consisting of the reproductive trophozoite stage and the environmentally robust cyst stage. Cysts are shed by infected hosts into the environment and can survive for months without losing their infectivity. While the parasite can be spread by various routes, such as person-to-person, animal contact or ingestion of contaminated food, water (drinking and recreational) is the most common method of transmission. This protozoan parasite has been recognized as a frequent cause of

waterborne disease because of its moderate chlorine tolerance and low infectious dose (Yoder et al., 2010).

Cryptosporidium are coccidian parasites that infect a wide variety of vertebrate hosts, including humans, and can cause diarrheal disease (cryptosporidiosis). Environmentally hardy oocysts are shed in the feces of infected humans and animals and are immediately infectious. The infectious dose is as few as 10 oocysts. Cysts are found on surfaces or in soil, food, or water that has been contaminated with feces. While the parasite can be spread in different ways, water (drinking and recreational) is the most common method of transmission (Desai et al., 2013).

Both giardiasis and cryptosporidiosis are global diseases causing similar symptoms, including diarrhea, abdominal cramps, nausea, and dehydration. In the US, giardiasis is the most common intestinal parasitic disease affecting humans, and an estimated 7,000 to 8,000 cases of cryptosporidiosis occur each year (Yoder et al., 2012a; Yoder et al., 2012b). In the ROK, Lee et al. (2011a) analyzed water samples quarterly at 6 intakes in the Han River for 6 conventional water treatment plants (WTPs) serving drinking water to Seoul, from 2000 to 2009. *Giardia* cysts in each of 10 l water were confirmed in 35.0% of intake water samples and the arithmetic mean was 1.65 cysts/10 l (range 0-35 cysts/10 l). The cysts were more frequently found in winter, when the mean density was 3.74 cysts/10 l compared to 0.80-1.08 cysts/10 l in other seasons. All treated water samples collected at 6 WTPs were negative for *Giardia* for 10 years. It was concluded that conventional water treatment in 6 Seoul WTPs appears to remove cysts effectively at their present levels in source water. A similar study was conducted looking for *Cryptosporidium* (Lee et al., 2010). *Cryptosporidium* oocysts were found in 22.5% of intake water samples, with an arithmetic mean of 0.65 oocysts/10 l (range 0-22 oocysts/10 l). All treated water samples collected at the 6 WTPs were negative for *Cryptosporidium* over the 10-year study. These results suggest that domestic wastewater from the urban region could be a source of *Giardia* and *Cryptosporidium* pollution.

Huh et al. (2009) studied the incidence and etiology of parasite-associated gastroenteritis between 2004 and 2006 in Gyeonggi-do. A total of 6,071 stool specimens were collected from patients with gastroenteritis in 6 general hospitals, and intestinal protozoans were detected in 208 samples (3.4%). The predominant parasite species was *G. lamblia* (152 cases; 2.5%), followed by *Entamoeba histolytica* (25 cases; 0.4%) and *Cryptosporidium parvum* (23 cases; 0.4%). Of the total number of positive samples, 23.1% (48/208) were obtained from adults aged 21 years of age and older, while 69.2% (144/208) were obtained from children under 5 years of age. The total prevalence in summer-autumn was 2.5 times higher than that in winter-spring. *Giardia lamblia* was detected throughout the year, the detection rate being higher in summer-autumn, while *E. histolytica* and *C. parvum* were rarely detected in winter (December - May).

The first record of an outbreak of giardiasis associated with drinking water was reported in 2010 (Cheun et al., 2013). In April 2010, residents in seven of eight households in a village in Jeollabuk Province had symptoms of abdominal pain accompanied by diarrhea. All were using

valley water, without chlorine sterilization and stored in a water tank as a provisional water supply source. *Giardia lamblia* was isolated from seven residents, and the overall incidence rate was 36%. This outbreak highlights the importance of continuous monitoring of water supplies in order to prevent and control the spread of parasites.

NOXIOUS PESTS OF KOREA

ARANEAE (spiders):

Family Miturgidae, genus *Cheiracanthium* (yellow sac spiders): There are no records of systemic reactions to Korean spider bites, but the bites of three species of *Cheiracanthium* are reported to be very painful.

Family Nephilidae, genus *Nephila*: the Joro spider, *Nephila clavata*, is a member of a group of golden orb-web spiders found around homes and training sites in Korea (Figure 20). Their webs are often head-high and may be difficult to see. A person walking through brush and some forested areas may run into the webs, sometimes with the spiders in the middle. The Joro spider is mildly venomous and it may cause pain, redness and limited tissue necrosis at the bite site.

Figure 20. *Nephila clavata*, the Joro spider, is a member of a group of golden orb spiders found around homes and training sites in Korea.

SCORPIONES (Scorpions)

Mesobuthus martensii: This scorpion is mainly found in localized moist sites within relatively dry and sparsely vegetated areas and sometimes digs a shallow burrow under large stones or pieces of wood. *Mesobuthus martensii* can grow to about 6 centimeters (2.4 in) long, with females usually slightly larger, and has a life span of about 4 to 6 years. It is typically yellowish to reddish-yellow with darker reddish-brown dorsal body color, nocturnal and tends to avoid humans, but stings readily if disturbed or stepped on. Stings may cause strong localized pain, swelling and redness, but serious envenomations are not common. Historically reported human fatalities due to stinging by this species have not been well documented. There is no currently available antivenom. For more information on this species see Keegan, 1980; Stockman and Ythier, 2010; and the AFPMB Living Hazards Database.

Figure 21. *Mesobuthus martensii* (Photo by Meseta Kurupira, released into the public domain)

CHILOPODA (centipedes)

Scolopendra subspinipes is occasionally encountered in rural or undeveloped areas. One of the largest scolopendrids (up to 230 mm long), this is a dangerous species because its bite can cause excruciating pain, swelling and redness, and the bite site often remains painful for several days. The relatively large fangs can inflict a wound large enough to readily allow secondary infections. Occasional systemic reactions have been reported due to envenomation by this species, but reported human fatalities have been rare and have not been well documented. Most other Korean centipedes inflict less toxic and less painful bites.

Figure 22. *Scolopendra subspinipes mutilans* (Photo by Yasunori Koide, shared under the Creative Commons Attribution-Share Alike 3.0 Unported license)

COLEOPTERA (beetles)

Meloidae (blister beetles): Painful blisters form after crushing these beetles against the skin. Though 19 species occur in the ROK, they are rare and are not attracted to lights.

Carabidae (bombardier beetles): Members of the genus *Brachinus* are capable of squirting irritating benzoquinones to a distance of 10 cm as a defensive measure. Three rare species are known from the ROK.

HYMENOPTERA (bees, wasps, and hornets)

The number of stinging hymenopteran species in Korea is small, and stings are serious mainly when complicated by allergic reactions or anaphylactic shock. In the absence of hypersensitivity, deaths from bee or wasp stings may be due directly to effects of venom injected during multiple stings (Keegan 1964). There are several hornet species endemic to Korea. The giant Asian hornet, *Vespa mandarinia* (family Vespidae), is the largest hornet in the world, with a body length of 50 mm and wingspan of 76 mm. It builds nests in tall grasses and other vegetation. Individual hornets carry an average of 3.5 µl of venom and defend their colonies by attacking en masse (Schmidt et al., 1986). Both this species and the Oriental hornet, *Vespa orientalis*, are responsible for a number of human deaths each year in South Korea, Japan, and other East Asian countries (Mebs, 2002). The Asian predatory wasp, *Vespa velutina*, also known as the Asian hornet or yellow-legged hornet, is a native of tropical and sub-tropical Indochina that was introduced into southern Korea near Yeongdo in 2003 and is spreading northward at the rate of 10-20 kilometers per year. This species can be aggressive and is well adapted to urban environments (Choi et al., 2012).

Figure 23. *Vespa mandarinia* (Photo by Terry Prouty, shared under the terms of the GNU Free Documentation License, Version 1.2)

In some areas of South Korea, stings from a primitive group of ants (family Formicidae, subfamily Ponerinae) belonging to the genus *Pachycondyla* are responsible for anaphylactic reaction rates similar to those of imported fire ants in the southern US (Cho et al., 2002b). Cases of anaphylaxis from stings of *Pachycondyla* have also been reported in Japan (Fukuzawa et al., 2002; Kim et al., 2001). Over 23% of residents surveyed in an ant-infested area demonstrated

sensitization to the venom of *Pachycondyla chinensis*, which occurs throughout the Far East Asian region including China and Japan. This species is a leaf litter inhabitant and generalist scavenger or predator (Wild, 2002).

LEPIDOPTERA (butterflies and moths)

The Oriental tussock moth, *Euproctis flava* (family Lymantriidae): The larvae, pupae and adults of *E. flava* are covered with hairs that cause dermatitis (papulourticarial reaction) when they contact human skin. Sensitization over a period of time exacerbates this effect. The wings and body of these small yellow moths are covered with yellow powder, composed of tiny dermatitis-producing hairs and scales. *Euproctis flava* may occur in great numbers during the summer and early fall seasons, and this species is attracted to lights. Large numbers of dermatitis cases often occur during adult emergence periods (mid-July through August) when rural inhabitants and military personnel stationed along the DMZ are exposed to these moths nightly. Army clinics in these areas have reported hundreds of cases of dermatitis during July and August. Inflammation of the eyes, nose and throat has also been reported. This moth poses a real health problem because adult moths will converge on any lighted area. In Shanghai, China, during a 3-month period in 1972, over 500,000 people were afflicted with sudden onset of skin eruptions (chiefly papules) and almost unbearable itching following exposure to airborne hairs of a related species, *E. similis* (Su, 1981). The best preventive measure is adequate screening to exclude moths from buildings.

Figure 24. *Euproctis similis* (Photo by IJmuiden, shared through GNU Free Documentation License, Version 1.2)

Some web-based links to additional information:

Armed Forces Pest Management Board Living Hazards Database

The Reptile Database (taxonomy, biology, & references)

Scorpion Information & References

American Arachnological Society

The World Spider Catalog

VENOMOUS SNAKES

There are five notably venomous land snakes (family Viperidae) reported from South Korea (Figures 22 - 26): *Gloydius blomhoffi* (most common), *Gloydius saxatilis* (rare), *Gloydius ussuriensis*, *Vipera berus*, and *Rhabdophis tigrinus*. The first three species belong to the subfamily Crotalinae and are often referred to as "mamushi" or "salmosa." The fourth viper

species found in Korea is *V. berus,* belonging in the subfamily Viperinae. In addition, there is one rear-fanged tiger keelback snake, *R. tigrinus*, belonging to the family Colubridae.

Figure 25. *Gloydius blomhoffi*

Figure 26. *Gloydius saxatilis*

Figure 27. *Gloydius ussuriensis*

Figure 28. *Vipera berus*

Figure 29. *Rhabdophis tigrinus*

Members of the genus *Gloydius* are true pit vipers and are closely related to the North American copperhead. They are found in rocky or brushy habitats throughout Korea and usually will not bite unless stepped on or harassed. While their venom has both hemotoxic and neurotoxic characteristics, it has one of the lowest toxicity values of all venomous snakes. Typical symptoms include pain and slight bleeding at the wound site, swelling, and rapid tender enlargement of the lymph nodes. Systemic symptoms generally begin 1-6 hours after being bitten and include double vision, neck rigidity, general achiness, difficulty in breathing, and reduced urine output. Fatalities are estimated to be about 1/1,000 among symptomatic humans, and not all bites result in envenomation. Most envenoming bites produce painful swelling, yet most patients recover without the need for antivenin or surgery. General supportive treatment should be provided and antivenin, if available, may be administered, but only by properly qualified clinicians. For antivenin information, refer to the WHO and/or Toxinology websites at the links below.

The venom of the tiger keelback snake, *R. tigrinus*, is primarily hemotoxic. Typical symptoms include local swelling, bleeding from the wound site, bleeding gums and hematuria. In severe cases, brain hemorrhage and acute renal failure have been reported. Several human deaths have been documented, mainly associated with the pet trade in Europe and Asia. In addition, *R. tigrinus* has nuchal glands located behind the head that produce toxic secretions (sequestered from eating toxic toads) that can get on the hands and can impair the vision of (and may even temporarily blind) humans when those secretions get into the eyes. While relatively docile, when disturbed or threatened, the snake may rear and spread the forepart of its body much like a cobra. It is mainly diurnal and commonly found in fields and mountain forests. Refer to the WHO and/or Toxinology websites at the links below).

PRECAUTIONS: Most snake bites in Korea occur from May through October. Most snakes found in Korea have a relatively mild disposition and will not attack if left alone. Bites usually occur when snakes are accidently stepped on or, more frequently, when they are harassed or

improperly handled. Wear boots when walking in grassy or rocky areas or conducting military training activities. Consistent guidance to military personnel is a must: "If you see a snake, DO NOT HANDLE IT."

At least three sea snakes (family Elapidae, subfamily Hydrophiinae) occur in marine waters around South Korea: *Hydrophis cyanocinctus* (the annulated sea snake), *Hydrophis hardwickii* (Hardwicke's broad-banded sea snake), and *Hydrophis platurus* (the pelagic sea snake). The pelagic sea snake also occurs far out in the open ocean. Sea snakes are generally even tempered and will usually avoid swimmers. Bites sometimes result when the snakes are accidentally trampled or brushed against on a beach or in adjacent shallow water, or when they are carelessly removed from nets, traps, or fishing gear. When stranded on beaches, sea snakes cannot strike but may turn to make an awkward snapping bite. Such bites are usually characterized by multiple pinhead-sized puncture wounds, in some of which broken teeth may be found. Of the three reported Korean species, *H. cyanocinctus* has by far the most potent venom, followed by *H. hardwickii* and *H. platurus*. Envenomation entails little or no localized pain but often tenderness and pain in the larger skeletal muscles. Sweating and thirst are common complaints, as is respiratory distress in severe cases.

SNAKE BITE: Reported cases of snake bite in military personnel conducting operations are infrequent. However, the fear of being bitten by a venomous snake can be a morale-degrading factor. Laboratory experiments have shown that most snake venoms contain a complex mixture of toxic factors, but the clinical signs of snakebite envenomization in humans are usually distinctive because viper venom is mainly hemotoxic. Venomous snakes inflict two types of bite: (1) a bite inflicted when the snake is seeking prey, in which the victim dies rapidly following injection of a large quantity of venom, and (2) a defensive bite, sometimes called a dry bite, with little or no venom injected, when the snake's instinctive objective is probably to escape. Studies of snakebite patients confirm that when venomous snakes bite humans, the bites nearly always are of the second type. More than half of reported victims have minimal or no envenomation. It is estimated that only about a quarter will develop serious or systemic poisoning.

The most common reaction following snakebite, whether or not the snake is venomous, is fright. Fear, to some degree, is present in all snakebite victims and often dominates the clinical picture. Emotional symptoms emerge rapidly, within minutes of the injury, while symptoms of systemic poisoning rarely appear until a half hour or more after the bite.

FIRST AID: The following steps should be taken if snakebite occurs (Mayo Clinic Staff, 2012):

1. Get the victim away from the snake. Keep the victim calm and quiet. Do not handle the snake or put yourself or others at risk of being bitten. Identify the snake, if possible. If it has been killed, keep it.

2. Immobilize the affected limb and apply direct pressure or compression over the bite. Do not

use tourniquets. If possible, keep the bite site below the level of the victim's heart. Note: incision and suction of the bite wound usually is ineffective in removing venom, and may even enhance inoculation of venoms. This can also greatly increase the probability of secondary infections.

3. Don't give the victim anything to eat or drink.

4. If the bite is on one of the victim's upper limbs, remove any rings or jewelry from that limb.

5. Arrange immediate evacuation of the victim. If there is no evidence of envenomation, keep the victim quiet and under observation.

6. An ice pack can be used intermittently to reduce pain. DO NOT pack a limb in ice or immerse it in ice water.

For information on snakebites, including first aid advice and current sources of antivenins worldwide, visit either of the following websites:

1. The WHO Searchable Snake/Antivenin Database

2. The Toxinology website (Australia based)

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Yun, S.M., B.G. Song, W.Y. Choi, W.I. Park, S.Y. Kim, J.Y. Roh, J. Ryou, Y.R. Ju, C. Park and E.H. Shin. 2012. Prevalence of tick-borne encephalitis virus in ixodid ticks collected from the Republic of Korea during 2011-2012. Osong Public Health and Research Perspectives, 3: 213-221.

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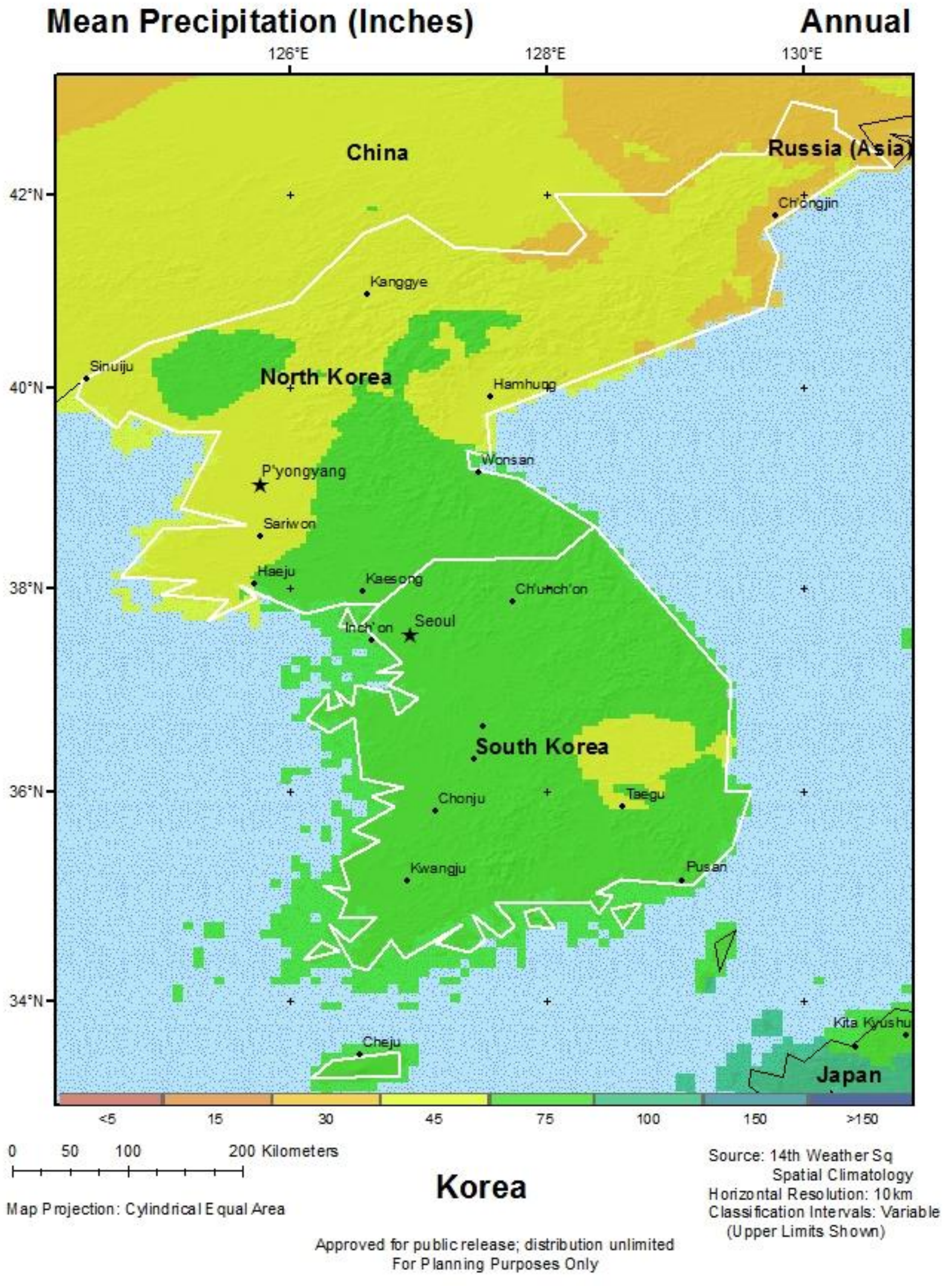
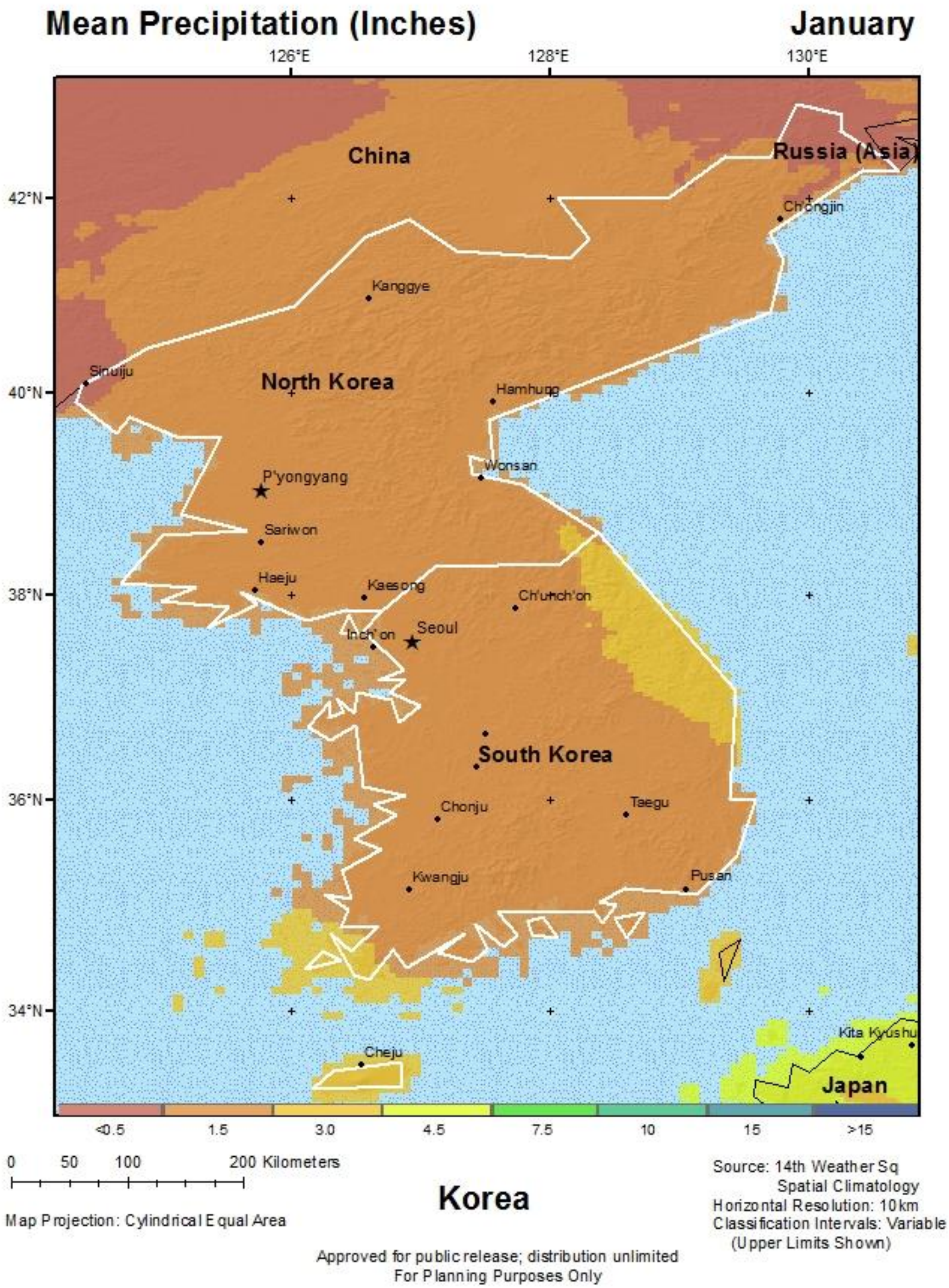
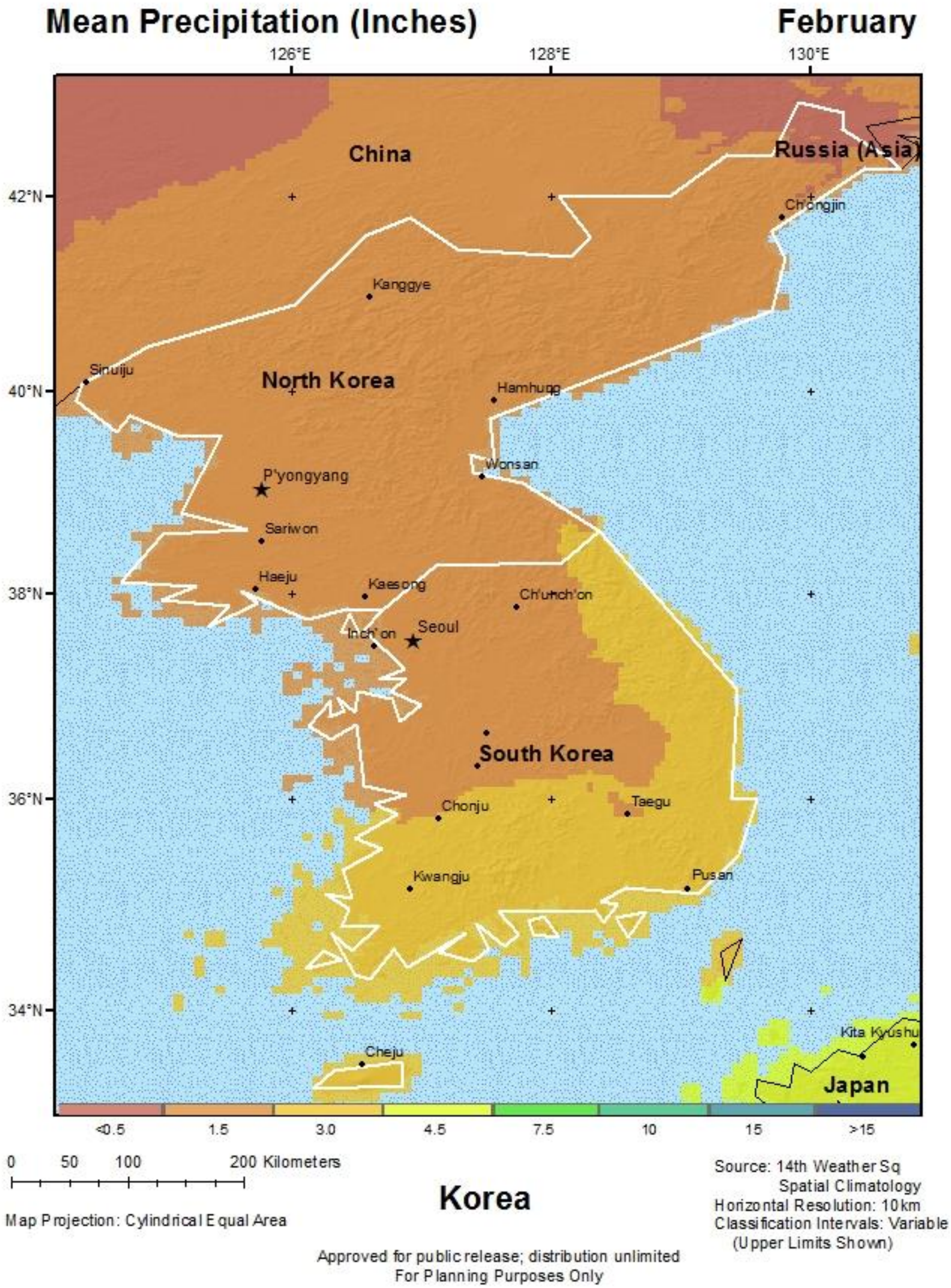
APPENDIX A - WEATHER DATA

This appendix contains annual and monthly means for precipitation and temperature on the Korean peninsula.





Mean Precipitation (Inches)
January
126°E
128°E
130°E
42°N
40°N
38°N
36°N
34°N
China
Russia (Asia)
Ch'ongjin
Kanggye
Sinuiju
North Korea
Hamhung
Wonsan
P'yongyang
Sariwon
Haeju
Kaesong
Ch'unch'on
Inch'on
Seoul
South Korea
Chonju
Taegu
Kwangju
Pusan
Kita Kyushu
Japan
Cheju
<0.5
1.5
3.0
4.5
7.5
10
15
>15
0
50
100
200 Kilometers
Korea
Map Projection: Cylindrical Equal Area
Source: 14th Weather Sq
Spatial Climatology
Horizontal Resolution: 10km
Classification Intervals: Variable
(Upper Limits Shown)
Approved for public release; distribution unlimited
For Planning Purposes Only


Mean Precipitation (Inches)
February
126°E
128°E
130°E
42°N
40°N
38°N
36°N
34°N
China
Russia (Asia)
Ch'ongjin
Kanggye
Sinuiju
North Korea
Hamhung
Wonsan
P'yongyang
Sariwon
Haeju
Kaesong
Ch'unch'on
Inch'on
Seoul
South Korea
Chonju
Taegu
Kwangju
Pusan
Cheju
Kita Kyushu
Japan
<0.5
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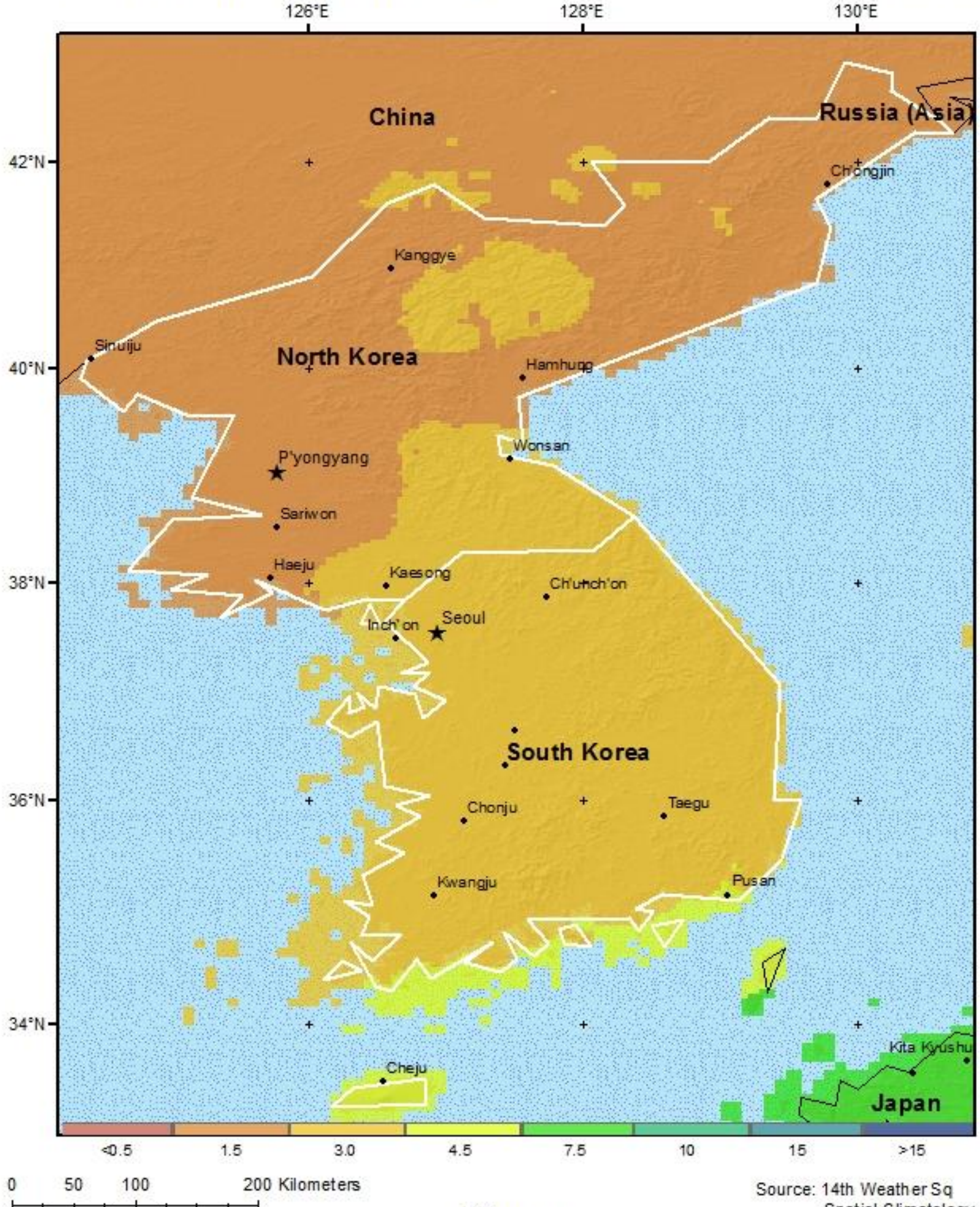
4.5
7.5
10
15
>15
0 50 100 200 Kilometers
Map Projection: Cylindrical Equal Area
Korea
Source: 14th Weather Sq
Spatial Climatology
Horizontal Resolution: 10km
Classification Intervals: Variable
(Upper Limits Shown)
Approved for public release; distribution unlimited
For Planning Purposes Only

Mean Precipitation (Inches) March

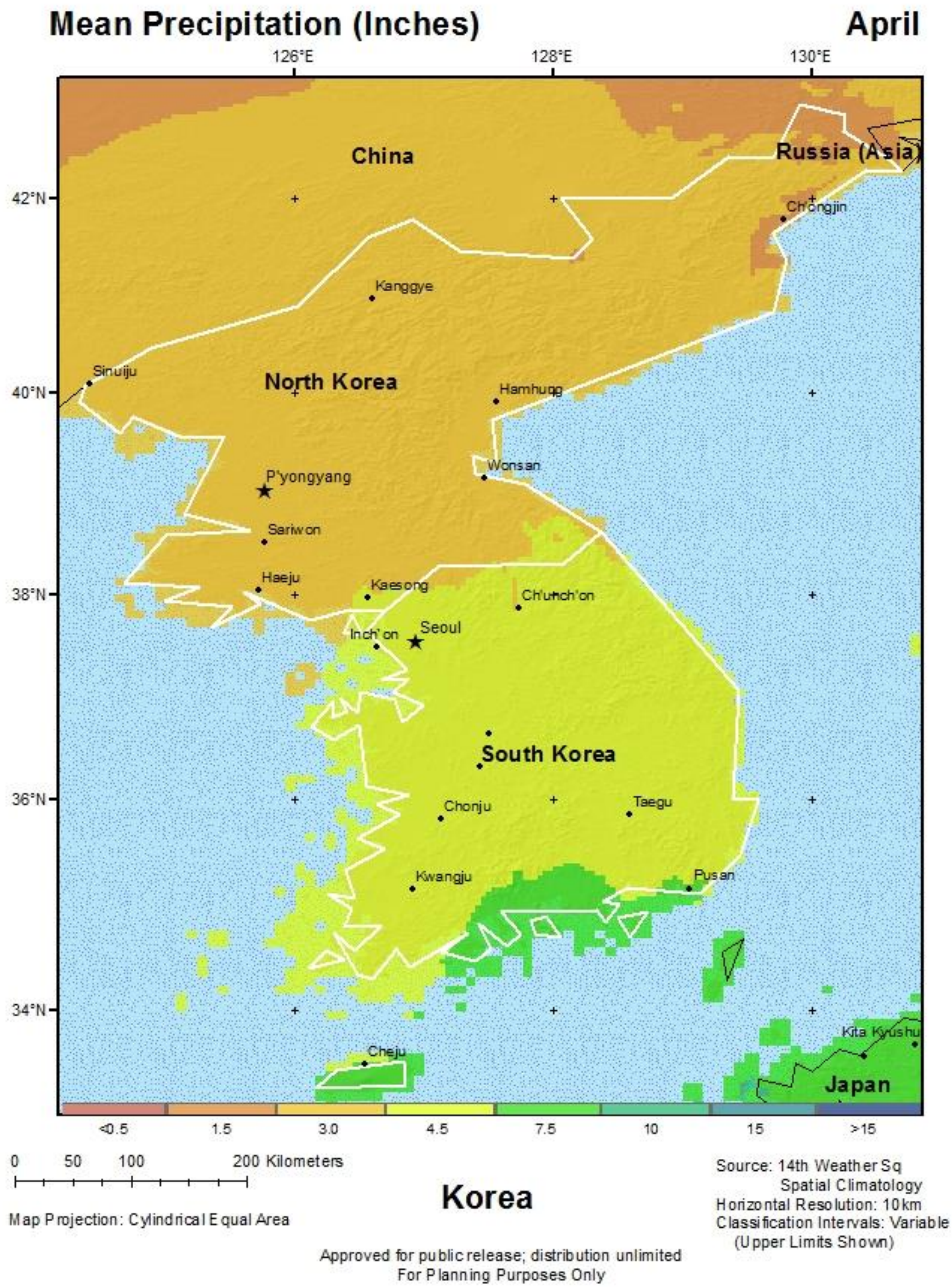


Map Projection: Cylindrical Equal Area

Korea

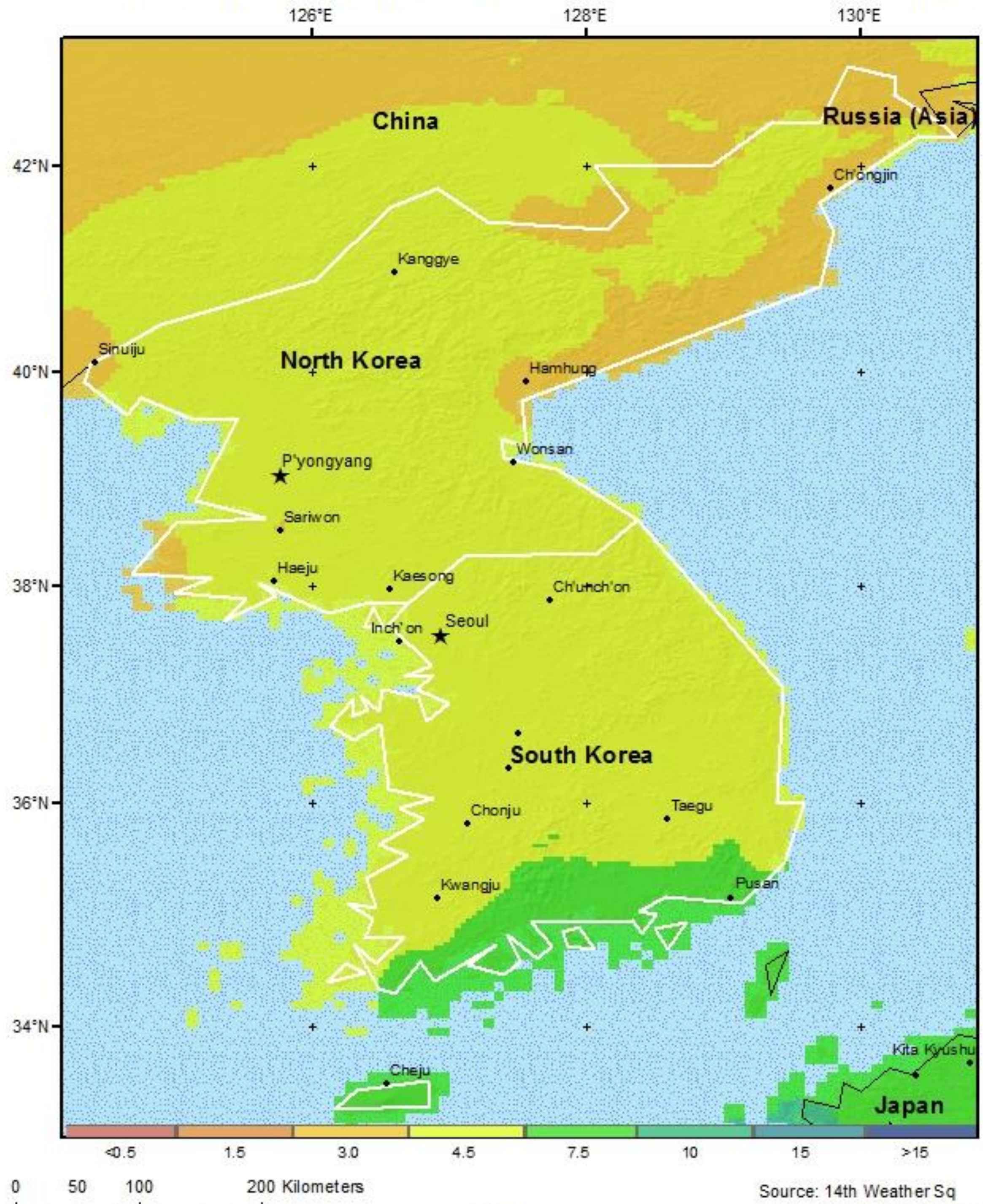
Source: 14th Weather Sq
Spatial Climatology
Horizontal Resolution: 10km
Classification Intervals: Variable
(Upper Limits Shown)

Approved for public release; distribution unlimited
For Planning Purposes Only



Mean Precipitation (Inches)
April
126°E
128°E
130°E
42°N
40°N
38°N
36°N
34°N
China
Russia (Asia)
Ch'ongjin
Kanggye
Sinuiju
North Korea
Hamhung
Wonsan
P'yongyang
Sariwon
Haeju
Kaesong
Ch'unch'on
Inch'on
Seoul
South Korea
Chonju
Taegu
Kwangju
Pusan
Cheju
Kita Kyushu
Japan
<0.5
1.5
3.0
4.5
7.5
10
15
>15
0
50
100
200 Kilometers
Map Projection: Cylindrical Equal Area
Korea
Source: 14th Weather Sq
Spatial Climatology
Horizontal Resolution: 10km
Classification Intervals: Variable
(Upper Limits Shown)
Approved for public release; distribution unlimited
For Planning Purposes Only

Mean Precipitation (Inches) **May**



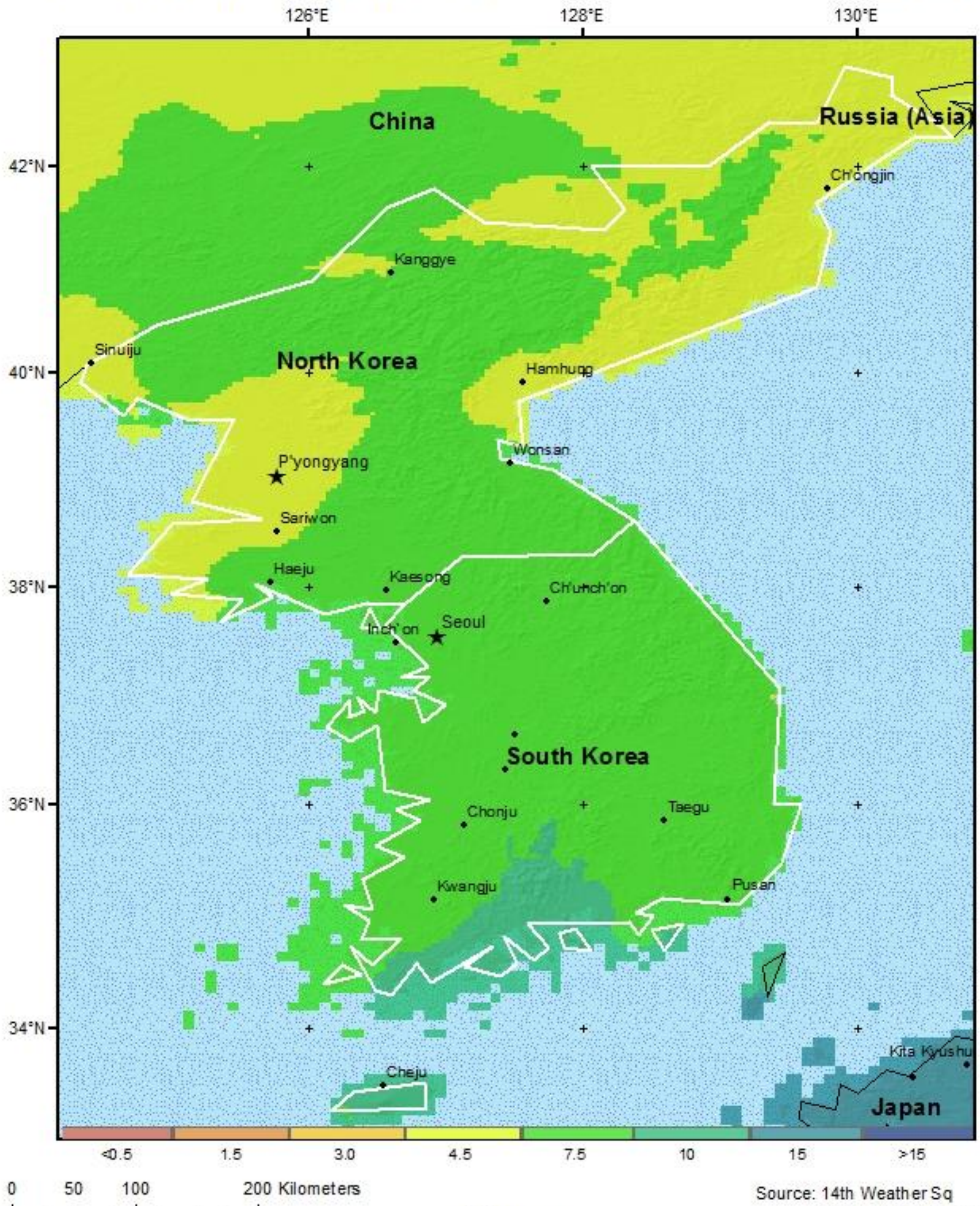
Map Projection: Cylindrical Equal Area

Korea

Source: 14th Weather Sq
Spatial Climatology
Horizontal Resolution: 10km
Classification Intervals: Variable
(Upper Limits Shown)

Approved for public release; distribution unlimited
For Planning Purposes Only

Mean Precipitation (Inches) June

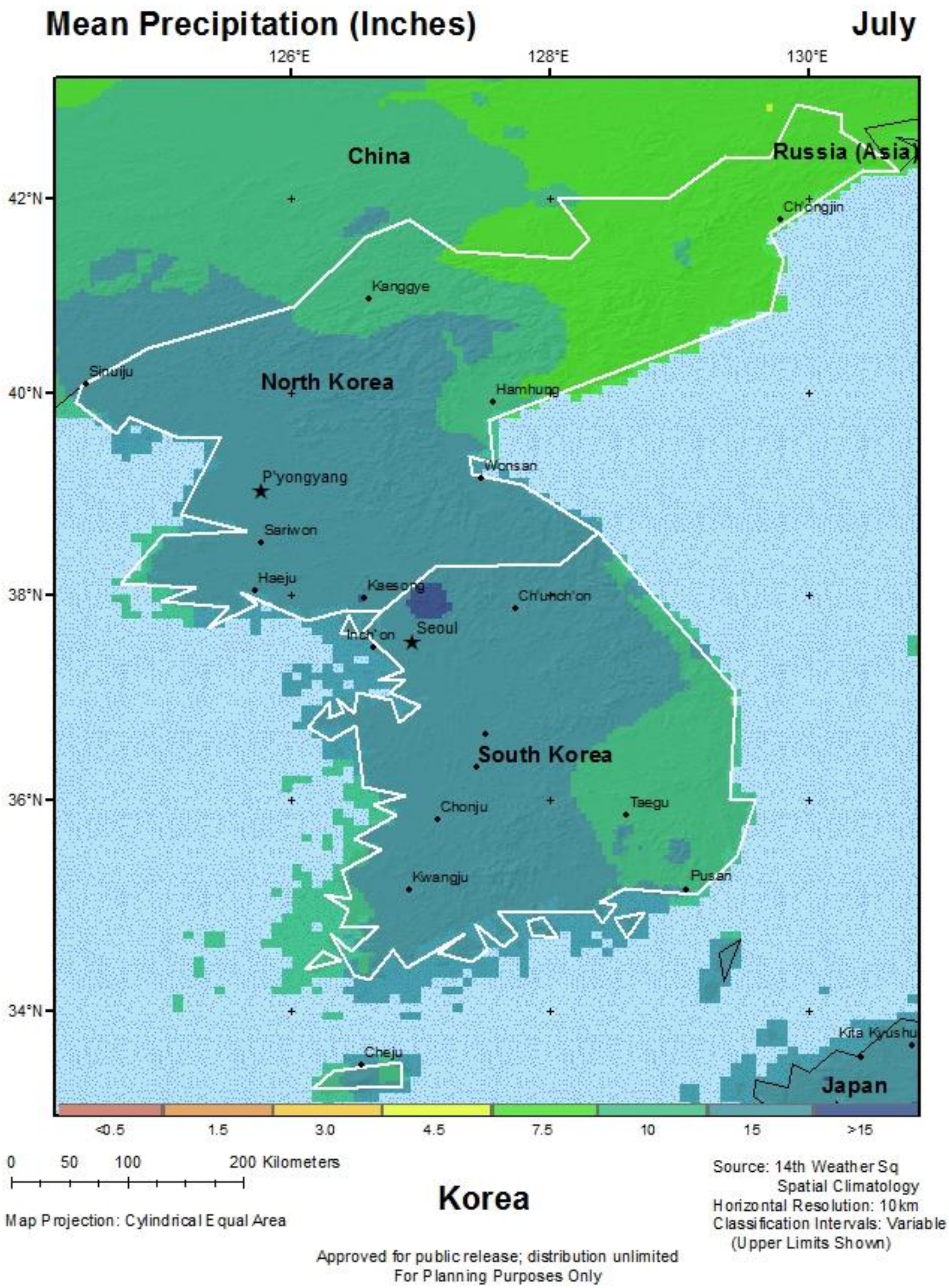


Map Projection: Cylindrical Equal Area

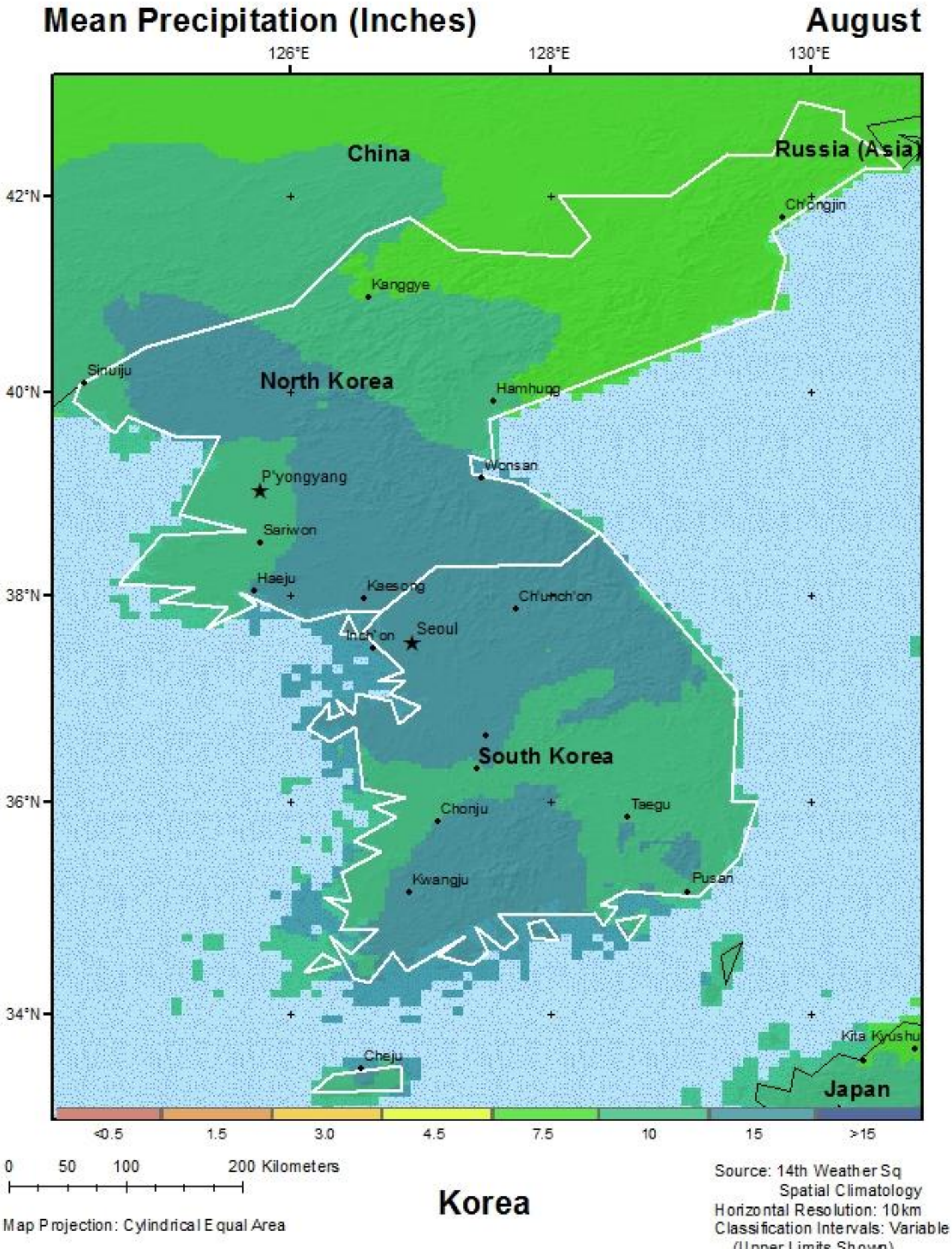
Korea

Source: 14th Weather Sq
Spatial Climatology
Horizontal Resolution: 10km
Classification Intervals: Variable
(Upper Limits Shown)

Approved for public release; distribution unlimited
For Planning Purposes Only



Mean Precipitation (Inches)
July
126°E
128°E
130°E
42°N
40°N
38°N
36°N
34°N
China
Russia (Asia)
Ch'ongjin
Kanggye
Sinuiju
North Korea
Hamhung
Wonsan
P'yongyang
Sariwon
Haeju
Kaesong
Ch'unch'on
Inch'on
Seoul
South Korea
Chonju
Taegu
Kwangju
Pusan
Kita Kyushu
Cheju
Japan
<0.5
1.5
3.0
4.5
7.5
10
15
>15
0
50
100
200 Kilometers
Map Projection: Cylindrical Equal Area
Korea
Source: 14th Weather Sq
Spatial Climatology
Horizontal Resolution: 10km
Classification Intervals: Variable
(Upper Limits Shown)
Approved for public release; distribution unlimited
For Planning Purposes Only

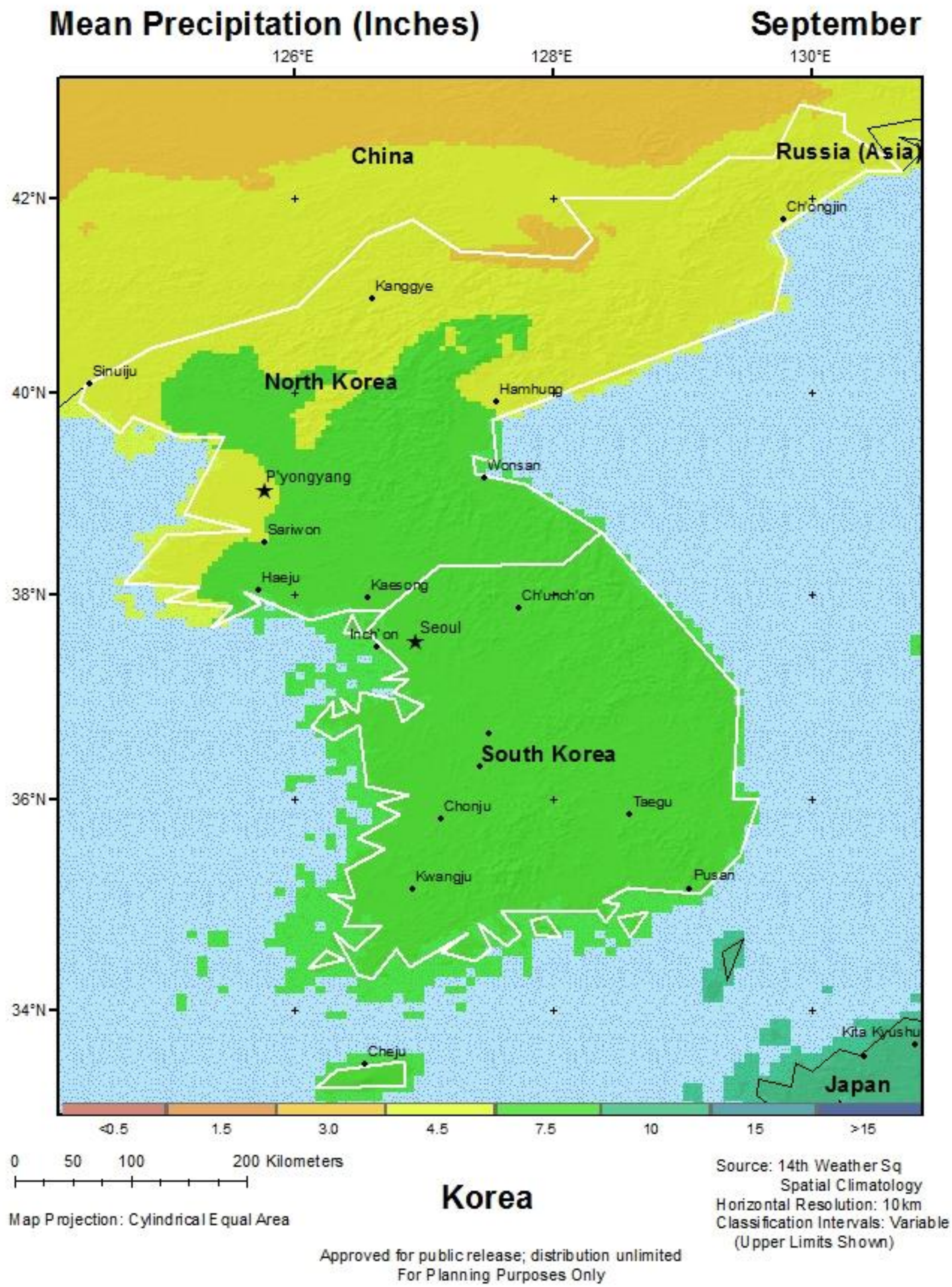


Map Projection: Cylindrical Equal Area

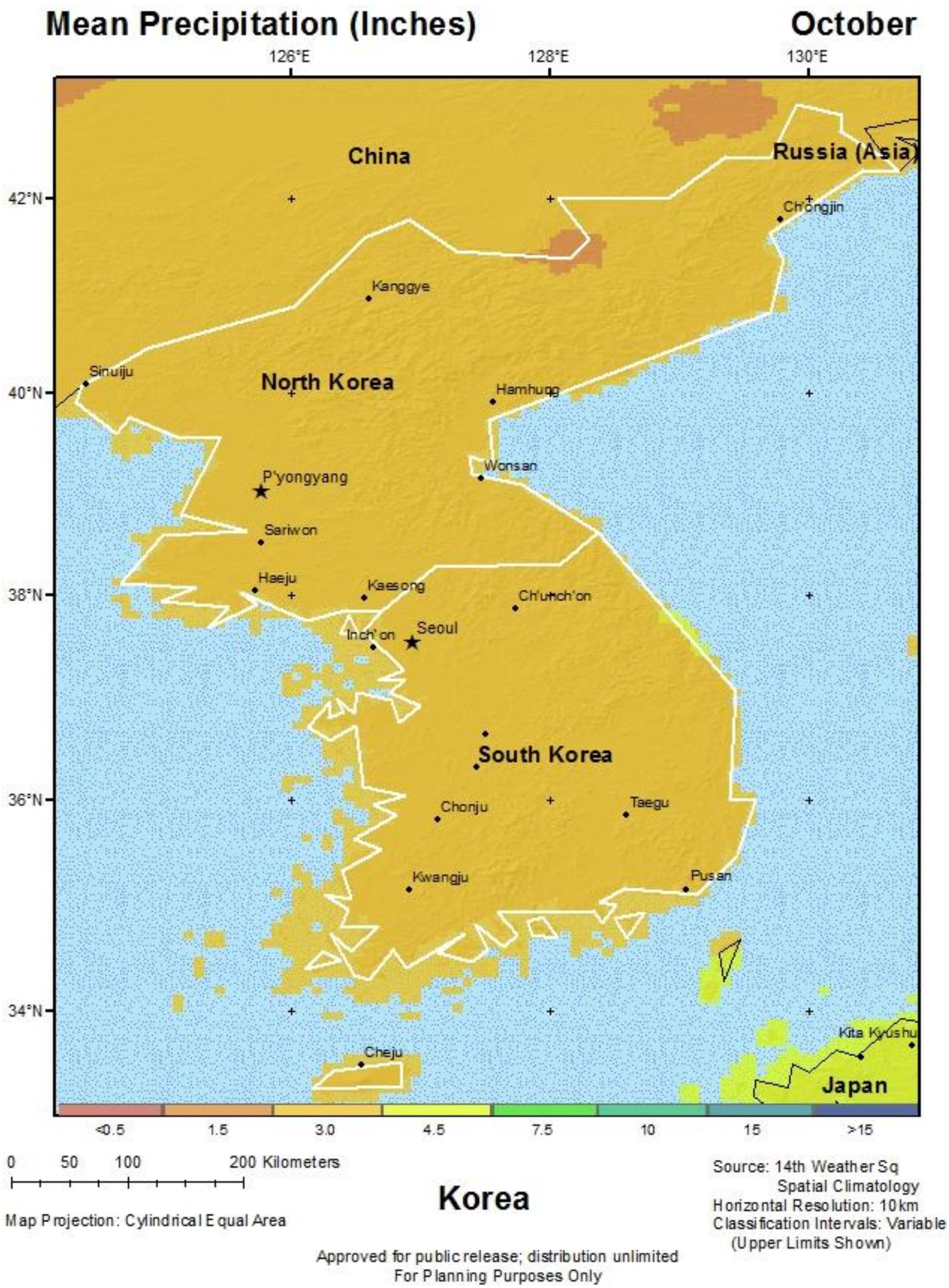
Korea

Source: 14th Weather Sq
Spatial Climatology
Horizontal Resolution: 10km
Classification Intervals: Variable
(Upper Limits Shown)

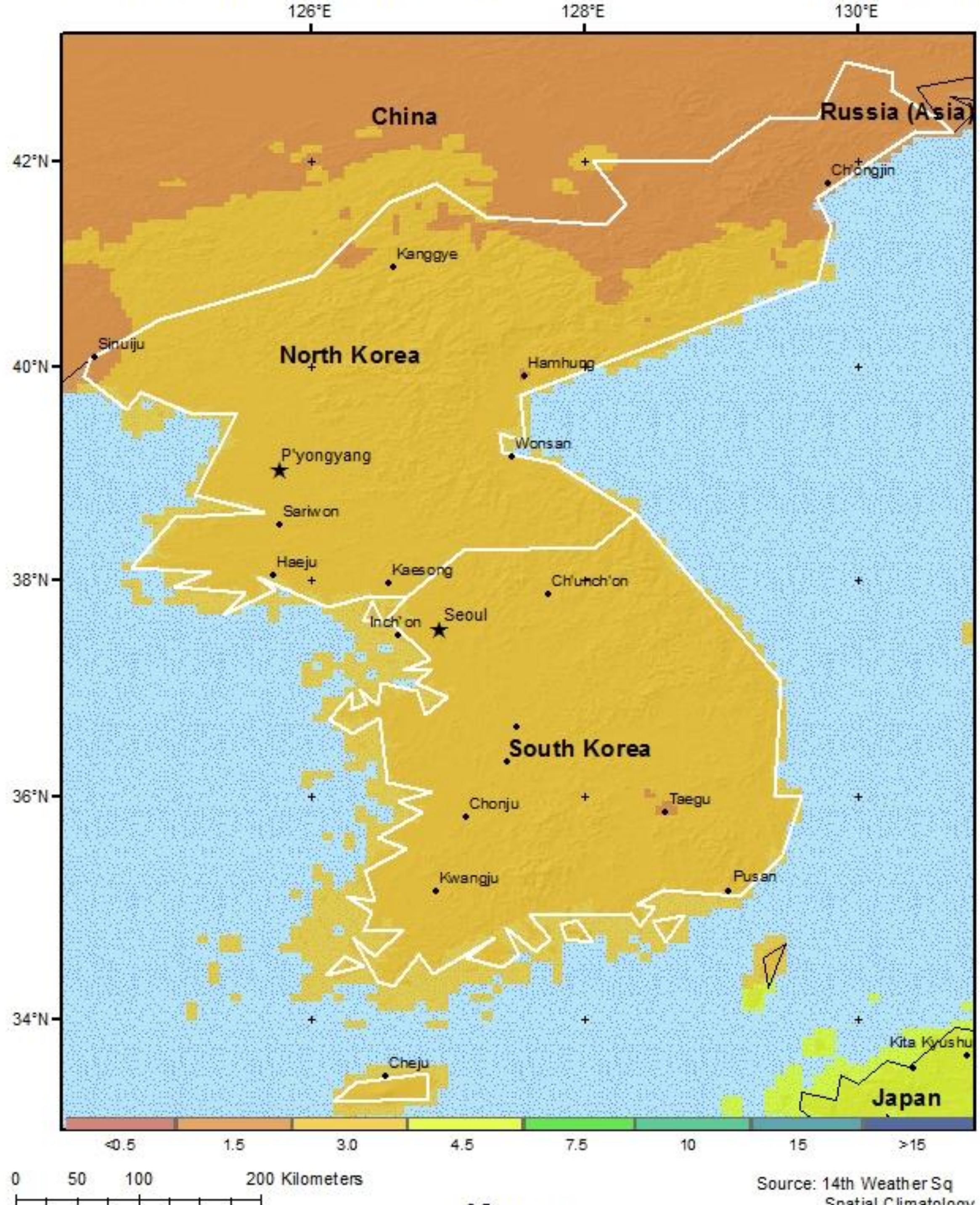
Approved for public release; distribution unlimited
For Planning Purposes Only



Mean Precipitation (Inches)
September
126°E
128°E
130°E
42°N
40°N
38°N
36°N
34°N
China
Russia (Asia)
Ch'ongjin
Kanggye
Sinuiju
North Korea
Hamhung
Wonsan
P'yongyang
Sariwon
Haeju
Kaesong
Ch'unch'on
Inch'on
Seoul
South Korea
Chonju
Taegu
Kwangju
Pusan
Kita Kyushu
Cheju
Japan
<0.5
1.5
3.0
4.5
7.5
10
15
>15
0
50
100
200 Kilometers
Map Projection: Cylindrical Equal Area
Korea
Source: 14th Weather Sq
Spatial Climatology
Horizontal Resolution: 10km
Classification Intervals: Variable
(Upper Limits Shown)
Approved for public release; distribution unlimited
For Planning Purposes Only


Mean Precipitation (Inches)
October
126°E
128°E
130°E
42°N
40°N
38°N
36°N
34°N
China
Russia (Asia)
Ch'ongjin
Kanggye
Sinuiju
North Korea
Hamhung
Wonsan
P'yongyang
Sariwon
Haeju
Kaesong
Ch'unch'on
Inch'on
Seoul
South Korea
Chonju
Taegu
Kwangju
Pusan
Cheju
Kita Kyushu
Japan
<0.5
1.5
3.0
4.5
7.5
10
15
>15
0 50 100 200 Kilometers
Map Projection: Cylindrical Equal Area
Korea
Source: 14th Weather Sq
Spatial Climatology
Horizontal Resolution: 10km
Classification Intervals: Variable
(Upper Limits Shown)
Approved for public release; distribution unlimited
For Planning Purposes Only

Mean Precipitation (Inches) — November

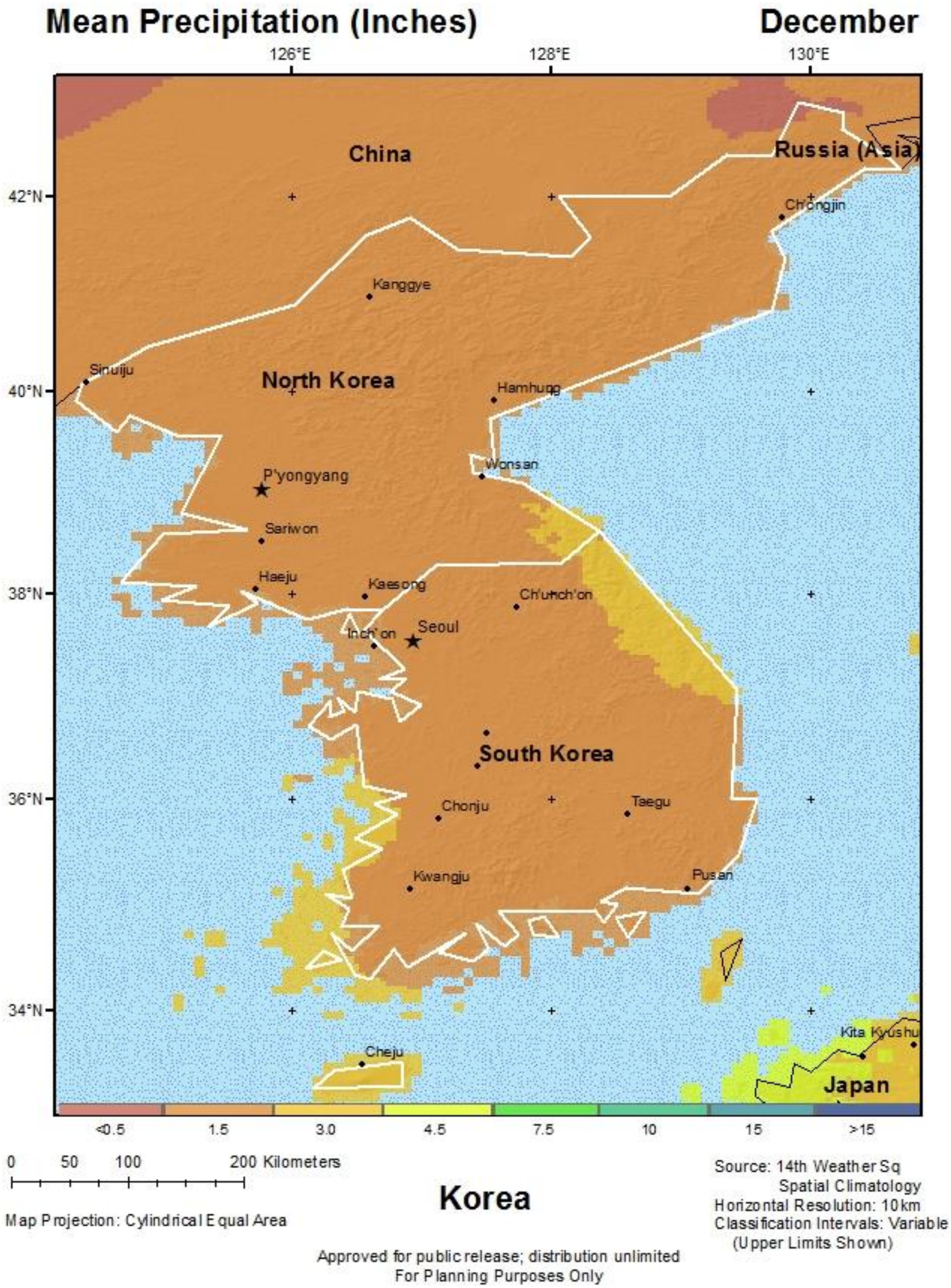


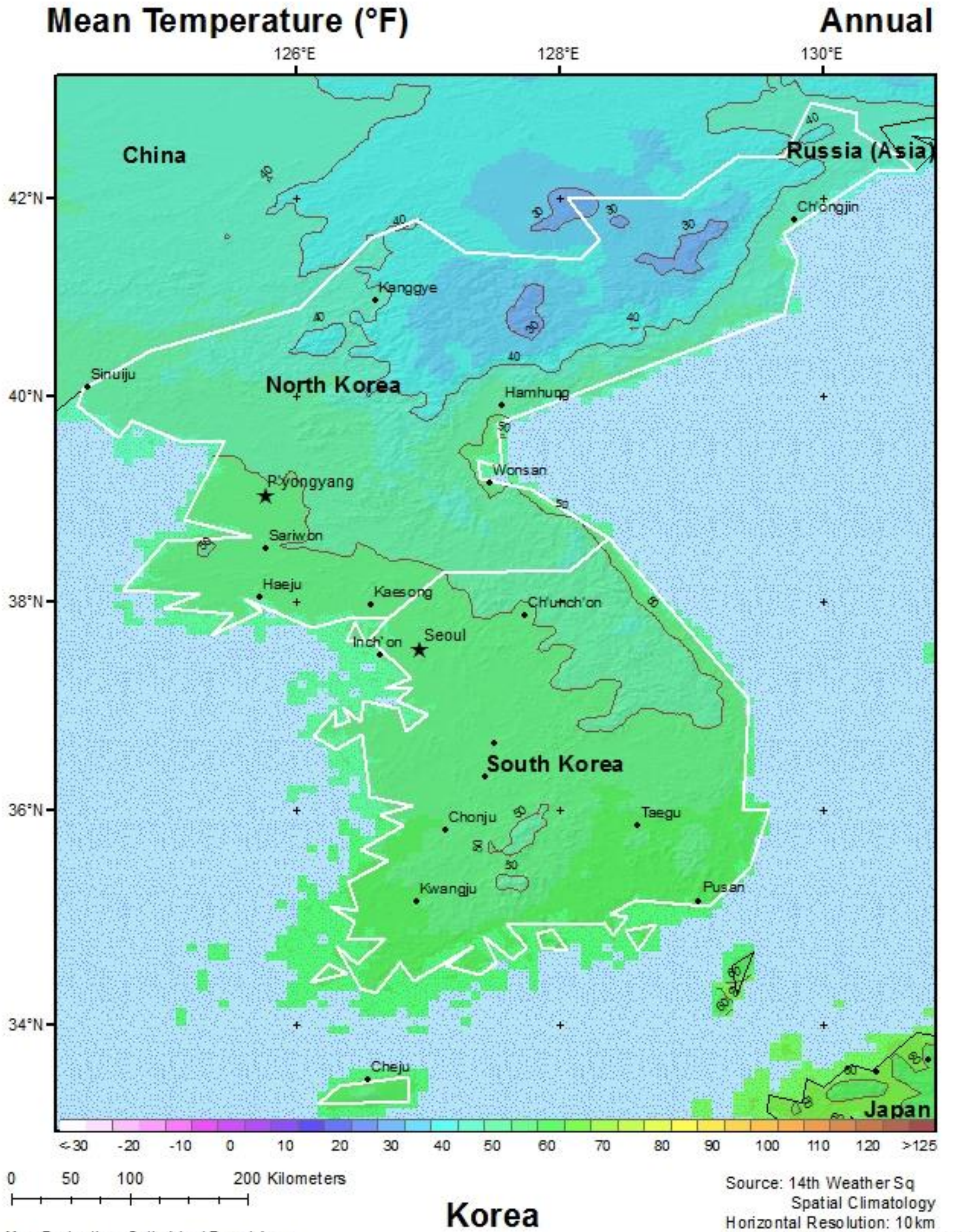
Map Projection: Cylindrical Equal Area

Korea

Source: 14th Weather Sq
Spatial Climatology
Horizontal Resolution: 10km
Classification Intervals: Variable
(Upper Limits Shown)

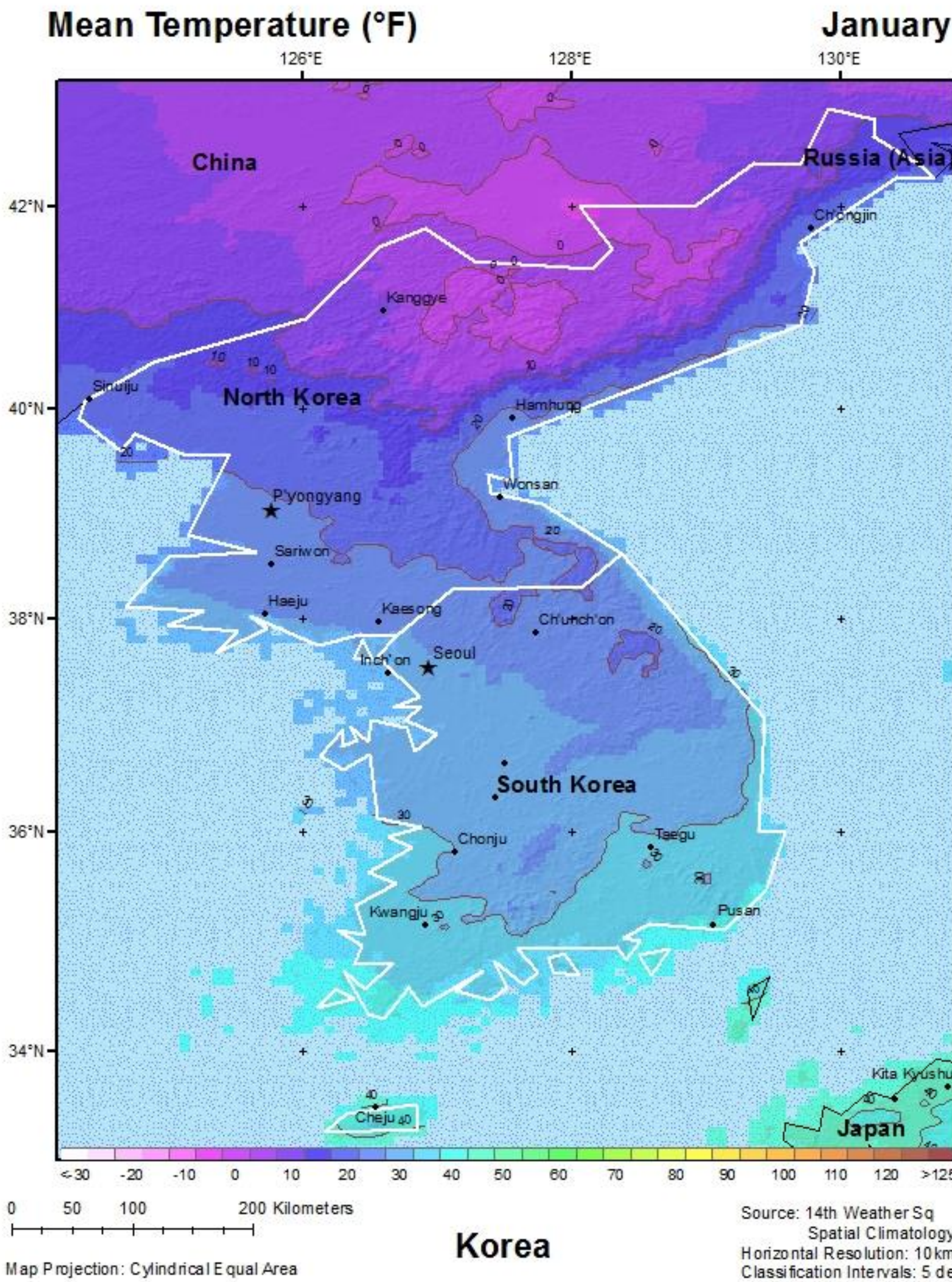
Approved for public release; distribution unlimited
For Planning Purposes Only


Mean Precipitation (Inches)
December
126°E
128°E
130°E
42°N
40°N
38°N
36°N
34°N
China
Russia (Asia)
Ch'ongjin
Kanggye
Sinuiju
North Korea
Hamhung
Wonsan
P'yongyang
Sariwon
Haeju
Kaesong
Ch'unch'on
Inch'on
Seoul
South Korea
Chonju
Taegu
Kwangju
Pusan
Cheju
Kita Kyushu
Japan
<0.5
1.5
3.0
4.5
7.5
10
15
>15
0 50 100 200 Kilometers
Map Projection: Cylindrical Equal Area
Korea
Source: 14th Weather Sq
Spatial Climatology
Horizontal Resolution: 10km
Classification Intervals: Variable
(Upper Limits Shown)
Approved for public release; distribution unlimited
For Planning Purposes Only



Korea

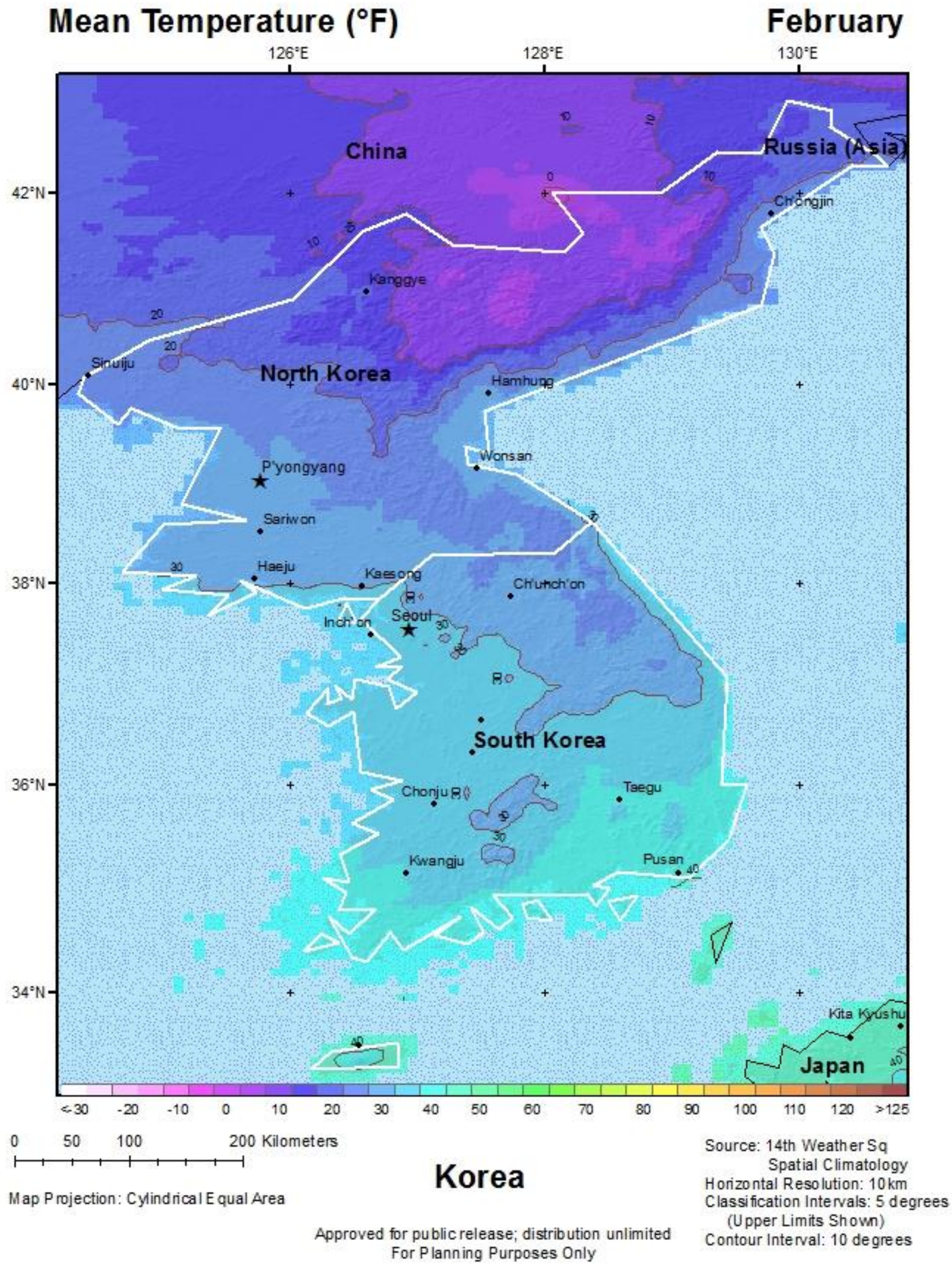
Approved for public release; distribution unlimited
For Planning Purposes Only



Korea

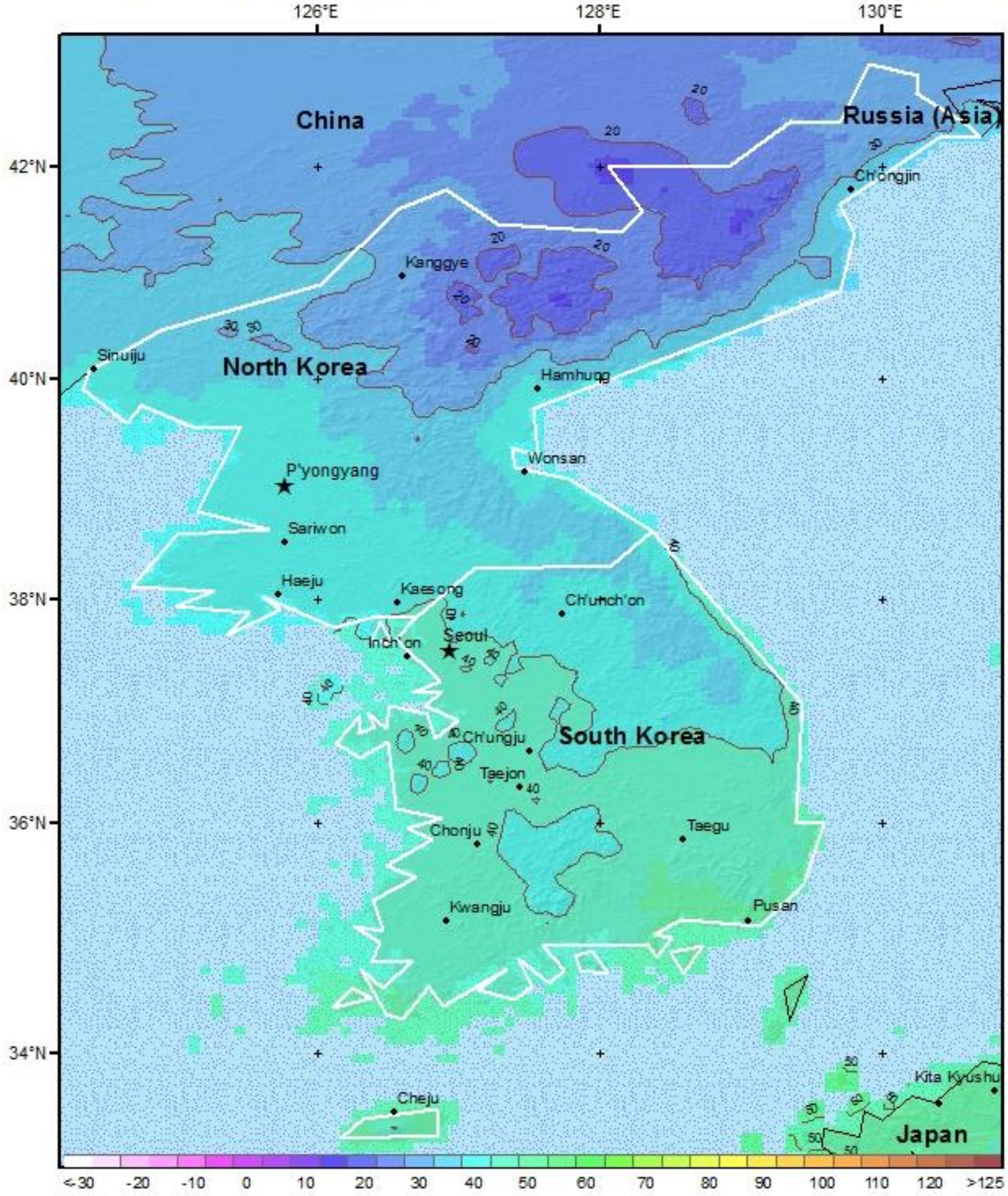
Approved for public release; distribution unlimited
For Planning Purposes Only

Source: 14th Weather Sq
Spatial Climatology
Horizontal Resolution: 10km
Classification Intervals: 5 degrees
(Upper Limits Shown)
Contour Interval: 10 degrees



Mean Temperature (°F)
February
126°E
128°E
130°E
42°N
40°N
38°N
36°N
34°N
China
Russia (Asia)
North Korea
South Korea
Japan
Ch'ongjin
Kanggye
Sinuiju
Hamhung
Wonsan
P'yongyang
Sariwon
Haeju
Kaesong
Ch'unch'on
Seoul
Inch'on
Chonju
Taegu
Pusan
Kwangju
Kita Kyushu
<-30 -20 -10 0 10 20 30 40 50 60 70 80 90 100 110 120 >125
0 50 100 200 Kilometers
Map Projection: Cylindrical Equal Area
Korea
Approved for public release; distribution unlimited
For Planning Purposes Only
Source: 14th Weather Sq
Spatial Climatology
Horizontal Resolution: 10km
Classification Intervals: 5 degrees
(Upper Limits Shown)
Contour Interval: 10 degrees

Mean Temperature (°F) March



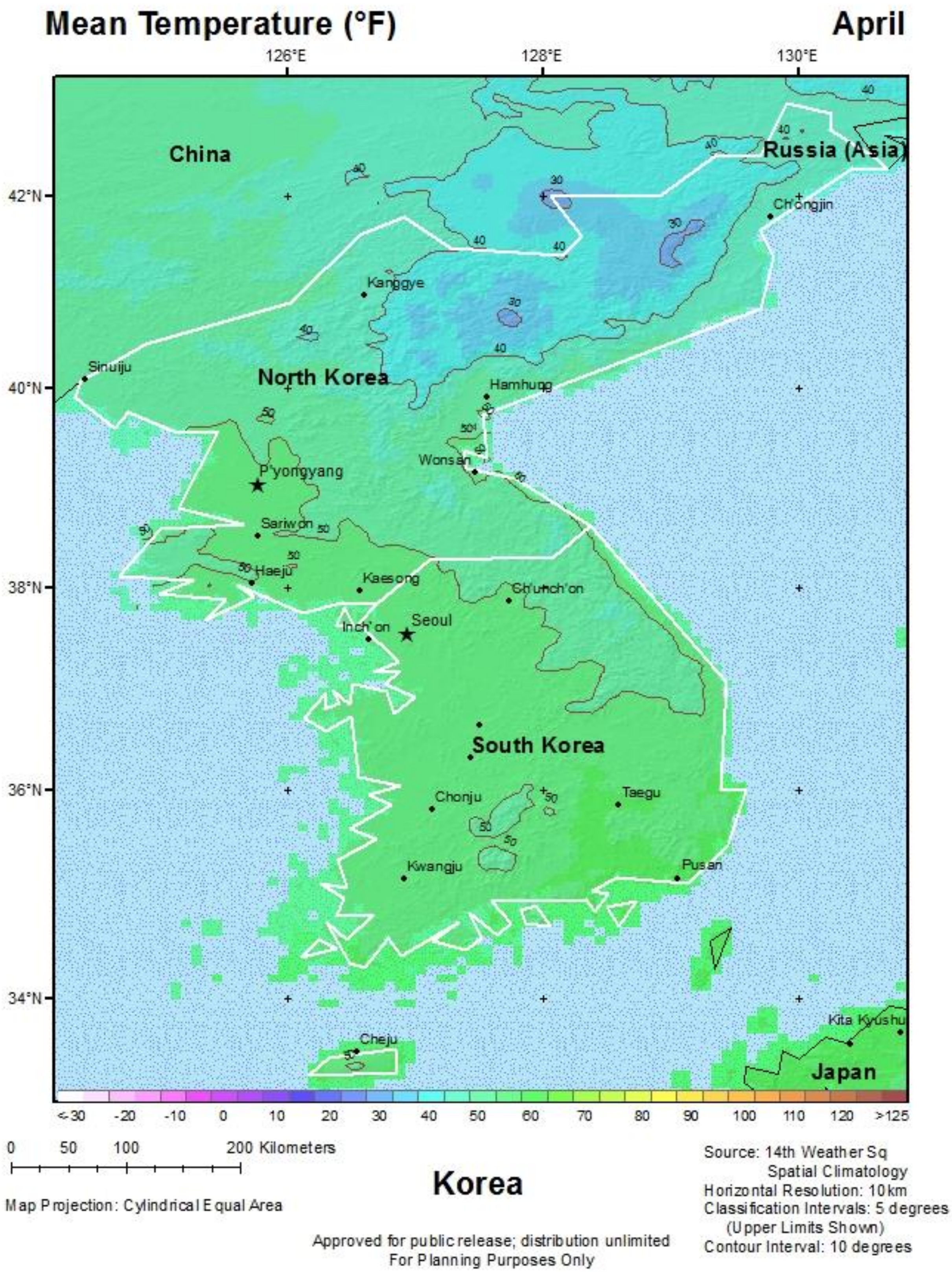
0 50 100 200 Kilometers

Map Projection: Cylindrical Equal Area

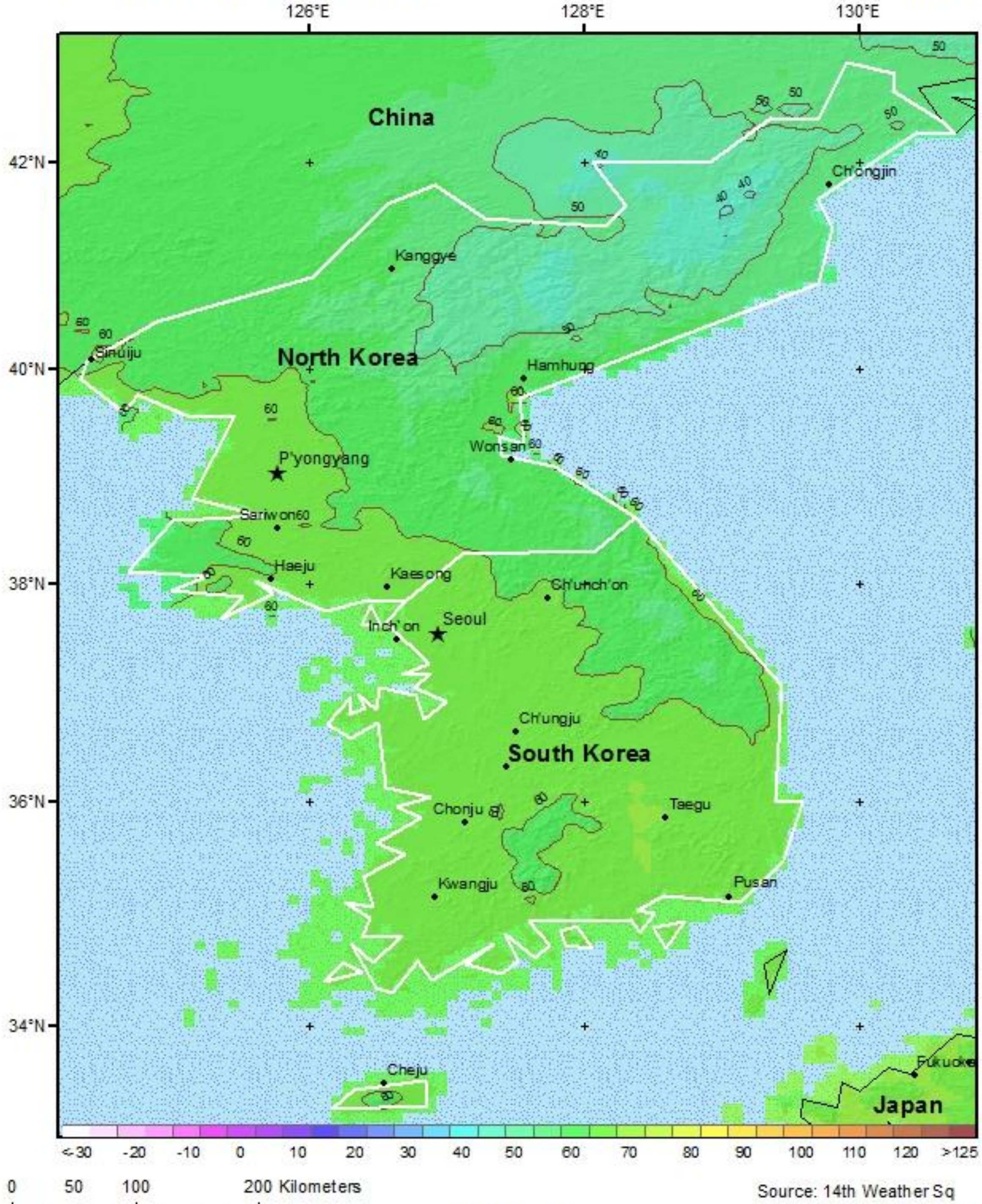
Korea

Approved for public release; distribution unlimited
For Planning Purposes Only

Source: 14th Weather Sq
Spatial Climatology
Horizontal Resolution: 10 km
Classification Intervals: 5 degrees
(Upper Limits Shown)
Contour Interval: 10 degrees


Mean Temperature (°F)
April
126°E
128°E
130°E
42°N
40°N
38°N
36°N
34°N
China
Russia (Asia)
North Korea
South Korea
Japan
Ch'ongjin
Kanggye
Sinuiju
Hamhung
P'yongyang
Wonsan
Sariwon
Haeju
Kaesong
Ch'unch'on
Inch'on
Seoul
Chonju
Taegu
Kwangju
Pusan
Cheju
Kita Kyushu
<-30 -20 -10 0 10 20 30 40 50 60 70 80 90 100 110 120 >125
0 50 100 200 Kilometers
Map Projection: Cylindrical Equal Area
Korea
Approved for public release; distribution unlimited
For Planning Purposes Only
Source: 14th Weather Sq
Spatial Climatology
Horizontal Resolution: 10 km
Classification Intervals: 5 degrees
(Upper Limits Shown)
Contour Interval: 10 degrees

Mean Temperature (°F) May



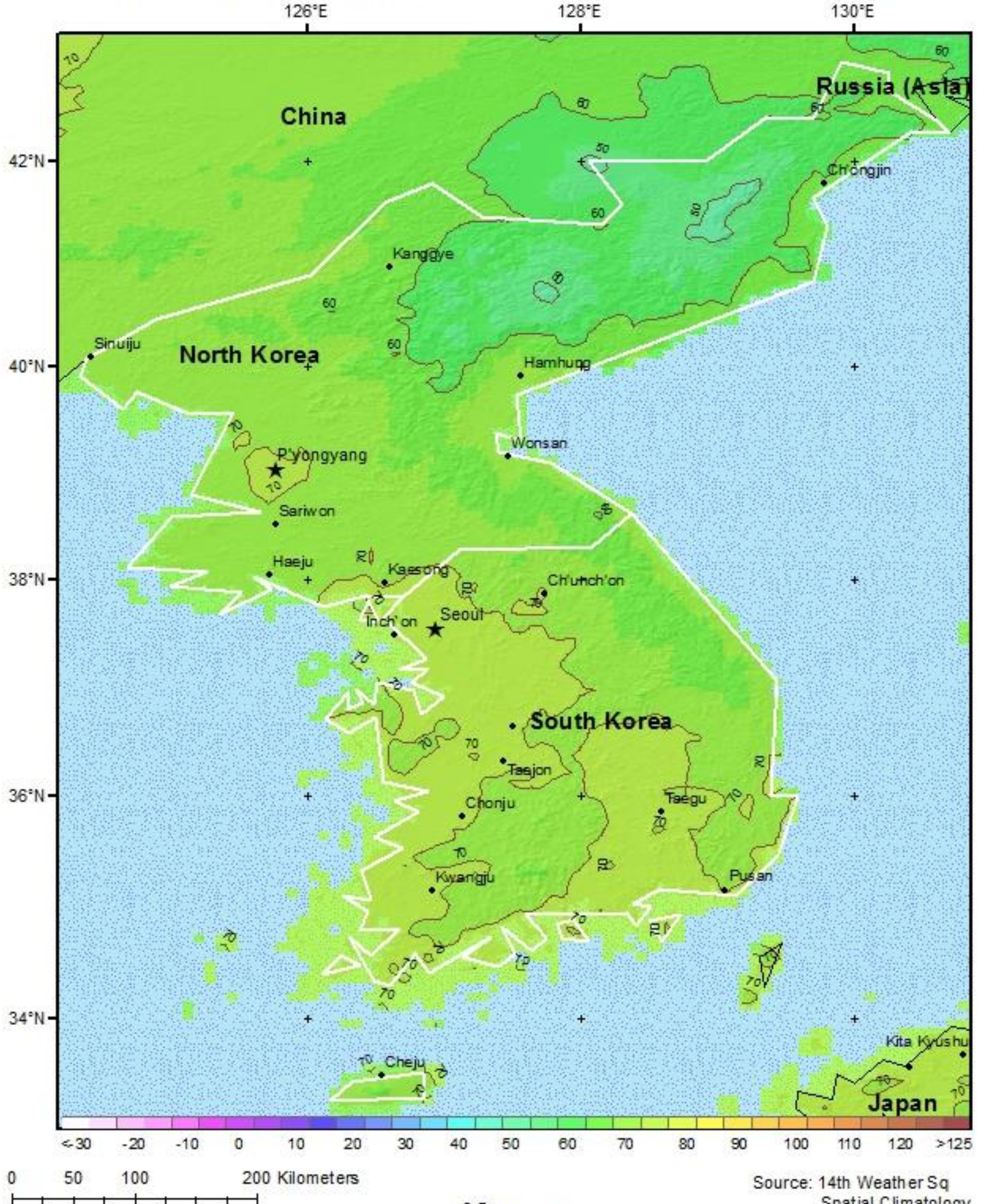
Map Projection: Cylindrical Equal Area

Korea

Approved for public release; distribution unlimited
For Planning Purposes Only

Source: 14th Weather Sq
Spatial Climatology
Horizontal Resolution: 10km
Classification Intervals: 5 degrees
(Upper Limits Shown)
Contour Interval: 10 degrees

Mean Temperature (°F) June

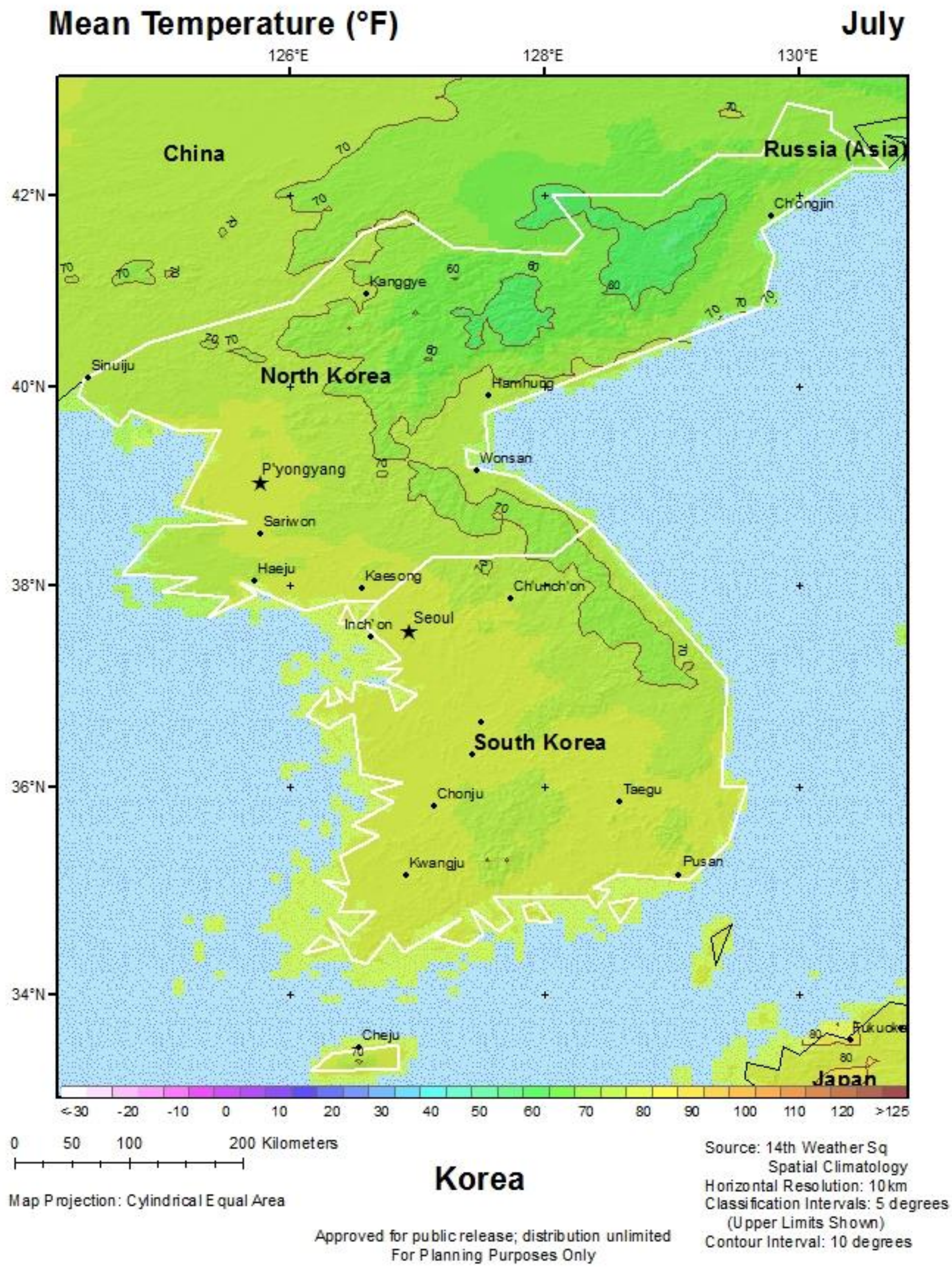


Map Projection: Cylindrical Equal Area

Korea

Approved for public release; distribution unlimited
For Planning Purposes Only

Source: 14th Weather Sq
Spatial Climatology
Horizontal Resolution: 10 km
Classification Intervals: 5 degrees
(Upper Limits Shown)
Contour Interval: 10 degrees



Mean Temperature (°F)
July
126°E
128°E
130°E
42°N
40°N
38°N
36°N
34°N
China
Russia (Asia)
North Korea
South Korea
Japan
Ch'ongjin
Kanggye
Sinuiju
Hamhung
Wonsan
P'yongyang
Sariwon
Haeju
Kaesong
Ch'unch'on
Inch'on
Seoul
Chonju
Taegu
Kwangju
Pusan
Cheju
Fukuoka
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110
120
>125
0
50
100
200 Kilometers
Map Projection: Cylindrical Equal Area
Korea
Source: 14th Weather Sq
Spatial Climatology
Horizontal Resolution: 10km
Classification Intervals: 5 degrees
(Upper Limits Shown)
Contour Interval: 10 degrees
Approved for public release; distribution unlimited
For Planning Purposes Only

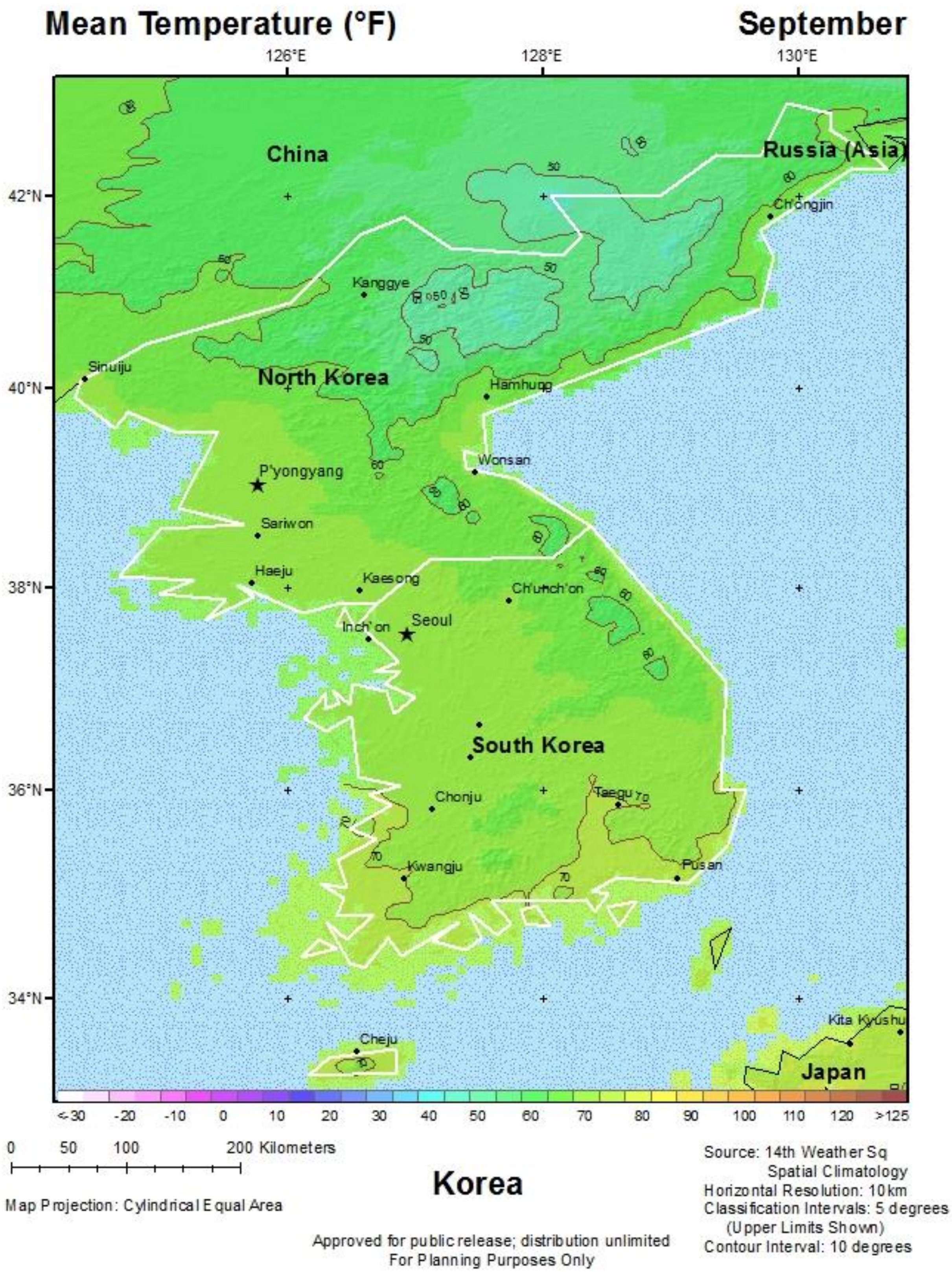
Mean Temperature (°F) August

Map Projection: Cylindrical Equal Area

Korea

Approved for public release; distribution unlimited
For Planning Purposes Only

Source: 14th Weather Sq
Spatial Climatology
Horizontal Resolution: 10km
Classification Intervals: 5 degrees
(Upper Limits Shown)
Contour Interval: 10 degrees



Mean Temperature (°F)
September
126°E
128°E
130°E
42°N
40°N
38°N
36°N
34°N
China
Russia (Asia)
Ch'ongjin
Kanggye
Sinuiju
North Korea
Hamhung
Wonsan
P'yongyang
Sariwon
Haeju
Kaesong
Ch'unch'on
Inch'on
Seoul
South Korea
Chonju
Taegu
Kwangju
Pusan
Cheju
Kita Kyushu
Japan
<-30
-20
-10
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30
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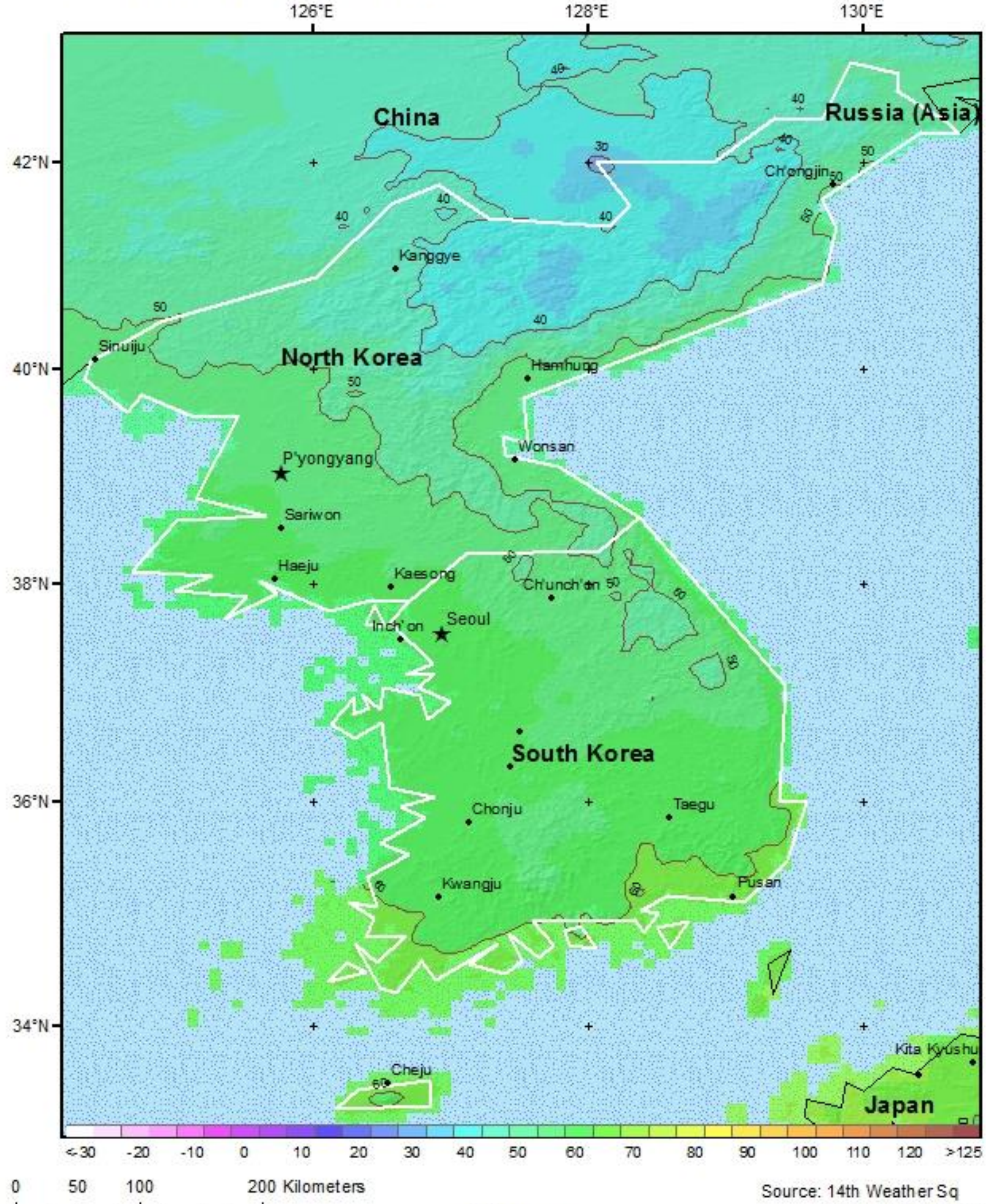
50
60
70
80
90
100
110
120
>125
0
50
100
200 Kilometers
Map Projection: Cylindrical Equal Area
Korea
Approved for public release; distribution unlimited
For Planning Purposes Only
Source: 14th Weather Sq
Spatial Climatology
Horizontal Resolution: 10km
Classification Intervals: 5 degrees
(Upper Limits Shown)
Contour Interval: 10 degrees

Mean Temperature (°F) October



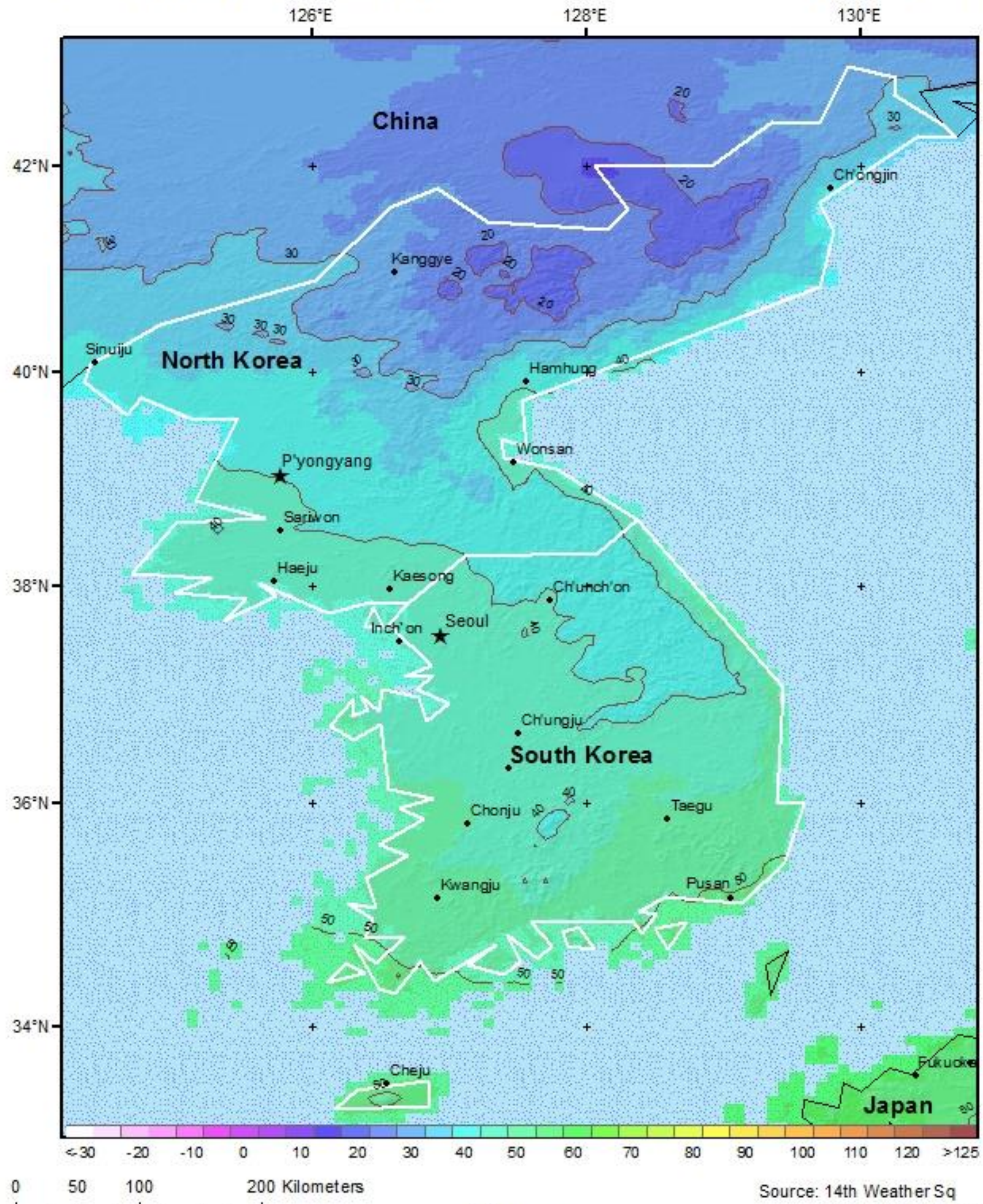
Map Projection: Cylindrical Equal Area

Korea

Approved for public release; distribution unlimited
For Planning Purposes Only

Source: 14th Weather Sq
Spatial Climatology
Horizontal Resolution: 10km
Classification Intervals: 5 degrees
(Upper Limits Shown)
Contour Interval: 10 degrees

Mean Temperature (°F) November

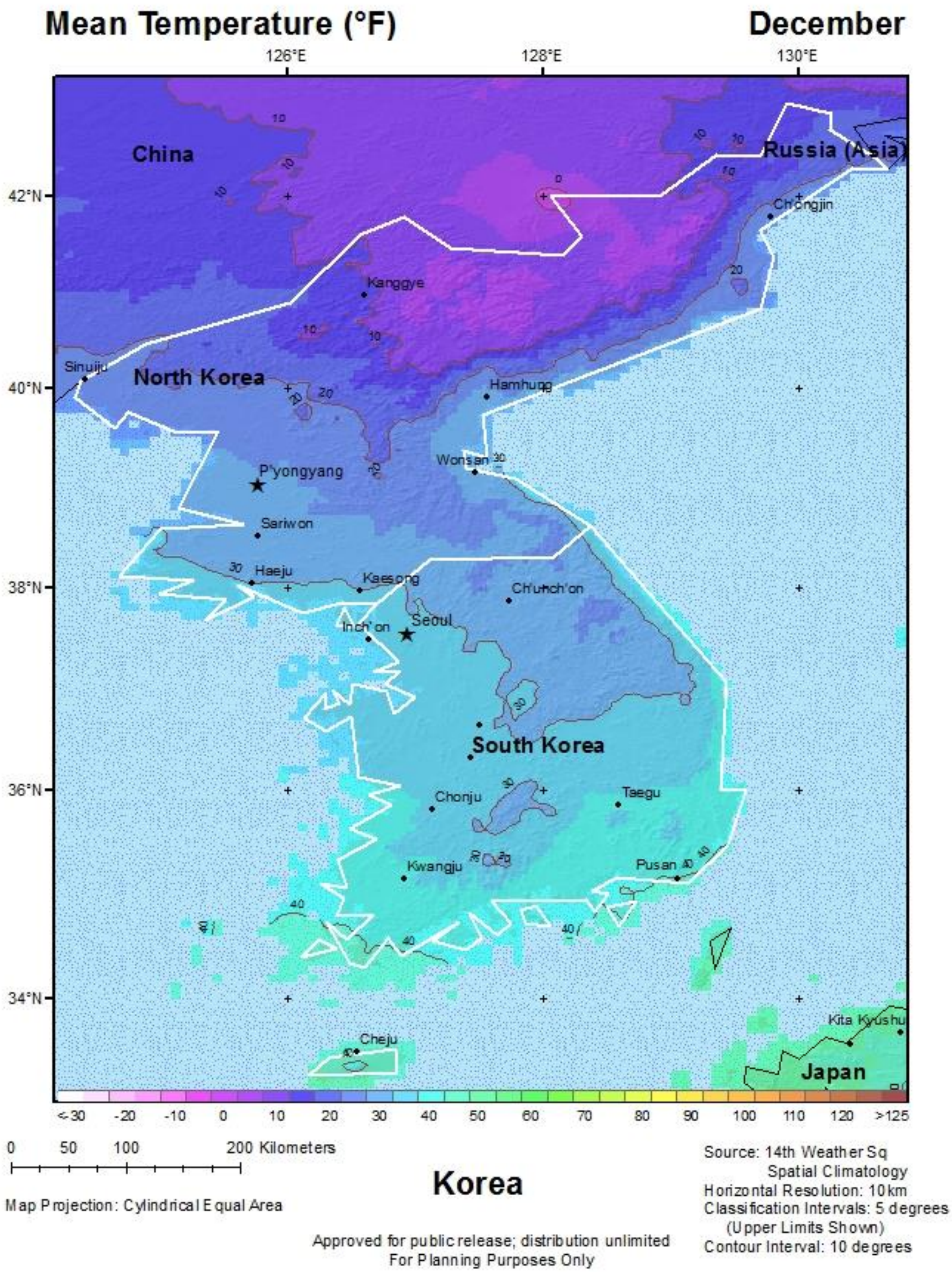


Map Projection: Cylindrical Equal Area

Korea

Approved for public release; distribution unlimited
For Planning Purposes Only

Source: 14th Weather Sq
Spatial Climatology
Horizontal Resolution: 10km
Classification Intervals: 5 degrees
(Upper Limits Shown)
Contour Interval: 10 degrees



Mean Temperature (°F)
December
126°E
128°E
130°E
42°N
40°N
38°N
36°N
34°N
China
Russia (Asia)
North Korea
South Korea
Japan
Ch'ongjin
Kanggye
Sinuiju
Hamhung
P'yongyang
Wonsan
Sariwon
Haeju
Kaesong
Ch'unch'on
Inch'on
Seoul
Chonju
Taegu
Kwangju
Pusan
Cheju
Kita Kyushu
<30 -20 -10 0 10 20 30 40 50 60 70 80 90 100 110 120 >125
0 50 100 200 Kilometers
Korea
Map Projection: Cylindrical Equal Area
Source: 14th Weather Sq
Spatial Climatology
Horizontal Resolution: 10km
Classification Intervals: 5 degrees
(Upper Limits Shown)
Contour Interval: 10 degrees
Approved for public release; distribution unlimited
For Planning Purposes Only

APPENDIX B - MOSQUITOES OF SOUTH KOREA

Those species that have been implicated in disease transmission are in bold type and are linked to WRBU species pages where you will find identification resources and bionomic information.

Family Culicidae

Subfamily Anophelinae

Anopheles (*Anopheles*)
An. *koreicus* Yamada & Watanabe
An. lesteri Baisas & Hu
An. *lindesayi japonicus* Yamada
An. pullus Yamada
An. sinensis Wiedemann
An. *sineroides* Yamada
An. kleini Rueda
An. belenrae Rueda

Subfamily Culicinae

Aedes (*Aedes*)
Ae. *esoensis* Yamada

Aedes (*Aedimorphus*)
Ae. *alboscutellatus* (Theobald)
Ae. *vexans nipponii* (Theobald)

Aedes (*Edwardsaedes*)
Ae. *bekkui* Mogi

Aedes (*Neomelaniconion*)
Ae. *lineatopennis* (Ludlow)

Aedes (*Stegomyia)*
Ae. albopictus (Skuse)
Ae. *chemulpoensis* Yamada
Ae. *flavopictus* Yamada
Ae. *galloisi* Yamada

Ochlerotatus
Oc. *alektorovi* Stackelberg
Oc. *hatorii* Yamada
Oc. japonicus japonicus (Theobald)

Oc. *koreicus* (Edwards)
Oc. *nipponicus* LaCasse & Yamaguti
Oc. *oreophilus* (Edwards)
Oc. *seoulensis* Yamada
Oc. togoi (Theobald)

Ochlerotatus (*Ochlerotatus)*
Oc. dorsalis (Meigen)

Armigeres (*Armigeres*)
Ar. subalbatus (Coquillett)

Coquillettidia (*Coquillettidia*)
Cq. *ochracea* (Theobald)

Culex (*Barraudius*)
Cx. *inatomii* Kamimura & Wada

Culex (*Culex*)
Cx. bitaeniorhynchus Giles
Cx. *jacksoni* Edwards
Cx. *mimeticus* Noe
Cx. *orientalis* Edwards
Cx. pipiens pallens Coquillett
Cx. pipiens molestus
Cx. pipiens quinquefasciatus Say
Cx. pseudovishnui Colless
Cx. *sinensis* Theobald
Cx. sitiens Wiedemann
Cx. tritaeniorhynchus Giles
Cx. *vagans* Wiedemann
Cx. *whitmorei* (Giles)

Culex (*Culiciomyia)*
Cx. kyotoensis Yamaguti & LaCasse
Cx. *sasai* Kano, Nitahara & Awaya
Culex (*Eumelanomyia*)
Cx. *hayashii* Yamada

Culex (*Lophoceraomyia*)
Cx. infatulus Edwards

Lutzia (*Metalutzia*)
Lt. *fuscanus* Wiedemann
Lt. *halifaxii* Theobald

Culex (*Neoculex*)
Cx. *rubensis* Sasa & Takahashi

Culiseta (*Culicella*)
Ct. nipponica LaCasse & Yamaguti

Culiseta (*Culiseta*)
Ct. *bergrothi* (Edwards)

Heizmannia (*Heizmannia*)
He. *lii* Wu

Mansonia (*Mansonioides*)
Ma. uniformis (Theobald)

Toxorhynchites (*Toxorhynchites*)
Tx. *christophi* (Portschinsky)

Tripteroides (*Tripteroides*)
Tp. *bambusa* (Yamada)

APPENDIX C - TICKS OF SOUTH KOREA

Family Argasidae

Argas boueti Roubaud and Colas-Belcour, 1933
Argas japonicas Yamaguti, Clifford and Tipton, 1968
Argas vespertilionis (Latreille, 1796)

Otobius megnini (Dugès, 1883)

Family Ixodidae

Amblyomma testudinarium Koch, 1844

Dermacentor silvarum Olenev, 1931

Haemaphysalis campanulata Warburton, 1908
Haemaphysalis concinna Koch, 1844
Haemaphysalis flava Neumann, 1897
Haemaphysalis japonica Warburton, 1908
Haemaphysalis longicornis Neumann, 1901
Haemaphysalis ornithophila Hoogstraal and Kohls, 1959
Haemaphysalis phasiana Saito, Hoogstraal and Wassef, 1974

Ixodes granulatus Supino, 1897
Ixodes nipponensis Kitaoka and Saito, 1967
Ixodes ovatus Neumann, 1899
Ixodes persulcatus Schulze, 1930
Ixodes pomerantzevi Serdjukova, 1941
Ixodes simplex Neumann, 1906
Ixodes tanuki Saito, 1964
Ixodes turdus Nakatsuji, 1942
Ixodes vespertilionis Koch, 1844

Rhipicephalus microplus (Canestrini, 1888)
Rhipicephalus sanguineus (Latreille, 1806)

APPENDIX D - FLIES ASSOCIATED WITH HUMANS IN SOUTH KOREA

Family Muscidae

Dichaetomyia
D. japonica Hori & Kurashasi

Fannia
F. canicularis (Linnaeus)
F. prisca Stein
F. scalaris (Fabricius)

Graphomya
G. maculata (Scopoli)
G. rufitibia Stein

Hydrotaea
H. occulta (Meigen)

Lispe
L. orientalis Wiedemann
Megophyra
M. multisetosa Shinonaga
Morellia
M. saishuensis Ouchi

Musca
M. bezzii Patton & Cragg
M. conducens Walker
M. domestica Linnaeus
M. hervei Villeneuve
M. sorbens Wiedemann
M. tempestiva Fallen

Muscina
M. angustifrons (Loew)
M. pascuorum (Meigen)
M. stabulans (Fallen)

Ophyra
O. leucostoma (Wiedemann)

Orthellia
O. coerulea (Wiedemann)

Phaonia
P. crassipalpis Shinonaga & Kano

Pyrellia
P. cadaverina (Linnaeus)

Stomoxys
S. calcitrans (Linnaeus)

Family Calliphoridae

Aldrichina
A. grahami (Aldrich)

Calliphora
C. lata Coquillett
C. vomitoria (Linnaeus)

Chrysomya
C. pinguis (Walker)

Hemipyrellia
H. ligurriens (Wiedemann)

Lucilia
L. ampullacea Villeneuve
L. bazini Seguy
L. caesar (Linnaeus)
L. illustris (Meigen)
L. porphyrina (Walker)

Onesia
O. koreana Kurahashi & Park

Phaenicia
P. cuprina (Wiedemann)
P. sericata (Meigen)
Protocalliphora
P. azurea (Fallen)

Triceratopyga
T. calliphorides Rohdendorf

Family Sarcophagidae

Bercaca
B. hemorrhoidalis (Fallen)

Blaesoxipha
B. filipjevi (Rohdendorf)
B. katoi Park & Kano
B. litoralis Villeneuve

Boettcherisca
B. peregrina (Robineau-Desvoidy)

Helicophagella
H. melanura (Meigen)

Horisca
H. hozawai (Hori)

Parasarcophaga
P. albiceps (Meigen)
P. brevicornis (Ho)

APPENDIX E - CHIGGERS OF SOUTH KOREA

Family Trombiculidae
Subfamily Trombiculinae
Tribe Trombiculini
Eltonella ichikawai (Sasa, 1952)

Leptotrombidium gemiticulum (Traub, Morrow and Lipovsky, 1958)
Leptotrombidium halidasys (Traub, Morrow and Lipovsky, 1958)
Leptotrombidium hiranumai (Kanda, 1942)
Leptotrombidium myoti (Ewing, 1929)
Leptotrombidium orientale (Schluger, 1948)
Leptotrombidium pallidum (Nagayo, Mitamura and Tamiya, 1919)
Leptotrombidium palpale (Nagayo, Mitamura and Tamiya, 1919)
Leptotrombidium pumile (Traub, Morrow and Lipovsky, 1958)
Leptotrombidium scutellare (Nagayo, Miyagawa, Mitamura, Tamiya and Tenjin, 1921)
Leptotrombidium subakamushi (Schluger, 1948)
Leptotrombidium subintermedium (Jameson and Toshioka, 1954)
Leptotrombidium tectum (Traub, Morrow and Lipovsky, 1958)
Leptotrombidium zetum (Traub, Morrow and Lipovsky, 1958)

Microtrombicula kyongkiensis Ah, 1964
Microtrombicula loomisi Ah, 1964
Microtrombicula miniopteri Ah, 1964
Microtrombicula pipistrelli Ah, 1964

Neotrombicula dubinini (Schluger, 1955)
Neotrombicula gardellai (Kardos, 1961)
Neotrombicula japonica (Tanaka, Kaiwa, Teramura and Kagaya, 1930)
Neotrombicula kwangneungensis Shin, Kim, Lee, Yoon and Shim, 1990
Neotrombicula mitamurai (Sasa, Hayashi, Kumada and Teramura, 1950)
Neotrombicula nagayoi (Sasa, Hayashi, Sato, Miura and Asahina, 1950)
Neotrombicula pomeranzevi (Schluger, 1948)
Neotrombicula southardi (Kardos, 1961)
Neotrombicula talmiensis (Schluger, 1955)
Neotrombicula tamiyai (Philip and Fuller, 1950)

Sasatrombicula chejudoensis Goff, 1984
Sasatrombicula koomori (Sasa and Jameson, 1954)

Tribe Schoengastiini
Ascoschoengastia arcaricola (Traub, Morrow and Lipovsky, 1958)
Ascoschoengastia kitajimai (Fukuzumi and Obata, 1953)

Cheladonta ikaoensis (Sasa, Sawada, Kano, Hayashi and Kumada, 1951)

Euschoengastia koreaensis Jameson and Toshioka, 1954

Helenicula miyagawai (Sasa, Kumada and Miura, 1951)

Neoschoengastia asakawai Fukuzumi and Obata, 1953
Neoschoengastia posekanyi Wharton and Hardcastle, 1946

Subfamily Gahrliepiinae
Walchia fragilis (Schluger, 1955)

Family Leeuwenhoekiidae
Subfamily Leeuwenhoekiinae
Tribe Leeuwenhoekiini
Shunsennia gracilis Ah, 1960
Shunsennia hertigi Traub, Morrow and Lipovsky, 1958
Shunsennia tarsalis Jameson and Toshioka, 1953

APPENDIX F - FLEAS OF SOUTH KOREA

Family Amphipsyllidae
Ctenophyllus armatus (Wagner)
Paradoxopsyllus curvispinus Miyajima & Koidzumi

Family Ceratophyllidae
Amalaraeus andersoni ioffi (Darskaya)

Ceratophyllus
C. anisus (Rothschild)
C. indages (Rothschild)
C. gallinae Dudolkina
C. tribulis Jordan

Malaraeus ioffi (Darskaya)

Monopsylus
M. anisus (Rothchild)
M. indages indages (Rothchild)

Nosopsyllus
N. fasciatus (Bosc)
N. nicanus Jordan

Paraceras melis (Walker)

Family Hystrichopsyllidae
Ctenophthalmus
C. congner congeneroides Wagner
C. pisticus pacificus Ioff & Scalon

Doratopsylla coreana Darskaya

Hystrichopsylla microti Scalon

Nearctopsylla ioffi Sychevsky

Neopsylla
N. bidentatiformis (Wagner)
N. specialis Jordan

Palaeopsylla

P. mogura Sakaguti & Jameson
P. sinica Ioff

Rhadinopsylla
R. attnuata Jameson & Sakagui
R. concava Ioff & Tiflov
R. insolita Jordan
R. valenti Darskaya

Stenoponia
S. montana Darskaya
S. sidimi Marikovsky

Family Ischnopsyllidae
Ischnopsyllus
I. comans Jordan & Rothschild
I. needhami Hsu
I. obscurus (Wagner)

Nycteridopsylla sakaguti Jameson & Suyemoto

Family Leptopsyllidae
Leptopsylla segnis (Schonherr)

Peromyscopsylla hamifer cuneata Johnson & Traub

Family Pulicidae
Ctenocephalides
C. canis (Curtis)
C. felis felis (Bouche)

Pulex irritans Linnaeus
Xenopsylla
X. astia (Rothschild)
X. cheopis (Rothschild)

APPENDIX G - PERSONAL PROTECTIVE MEASURES (PPMs)

A comprehensive guide to PPMs is available from the AFPMB as Technical Guide 36. PPMs are the first line of defense against arthropod-borne disease and are often the only protection for military personnel in the field. Proper wearing of the uniform and appropriate use of repellents (permethrin on the uniform and DEET or other AFPMB-approved repellent on exposed skin) can provide high levels of protection against blood-sucking arthropods. The uniform fabric itself is a significant mechanical barrier to mosquitoes and other blood-sucking arthropods and should be worn to cover as much skin as possible, if weather and physical activity permit.

When operating in tick-infested areas, pants should be bloused into boots to prevent access to the skin by crawling arthropods. Check yourself frequently when in tick-infested areas. Upon returning from such areas, remove all clothing and examine yourself for ticks. Infected ticks may require several hours of feeding before pathogens are transmitted. Therefore, personnel in tick-infested areas should check themselves frequently and remove ticks as soon as possible.

If ticks become attached, the simplest and best method of removal is a slow, steady pull with a pair of tweezers. Don't squeeze the body but grasp the tick where the mouthparts enter the skin and pull firmly until the tick is extracted. Be careful not to break off the mouthparts in the skin. Wipe the bite area with an antiseptic. If hands have touched the tick during removal, wash them thoroughly with soap and water or an antiseptic, since tick secretions may contain pathogens.

APPENDIX H - CHEMICAL CONTROL OF PESTS AND VECTORS

More detailed recommendations for the selection and use of pesticides in field situations worldwide, including the Koreas, during contingency operations or exercises, can be found in AFPMB Technical Guide 24, Contingency Pest Management Guide. This guide is a concise reference to National Stock Number (NSN)-listed pesticides and equipment available through DoD supply channels for contingency and garrison use. It covers intended uses, application methods, pesticide dilution formulas, and dispersal equipment. Technical Guide 24 also provides information on surveillance, trapping, safety, PPM, military air transport of hazardous chemicals, and US military points of contact overseas who can provide information on vector-borne disease control in their respective areas of the world. Additional pesticide application resources can be accessed at the DoD Equipment Helpdesk.

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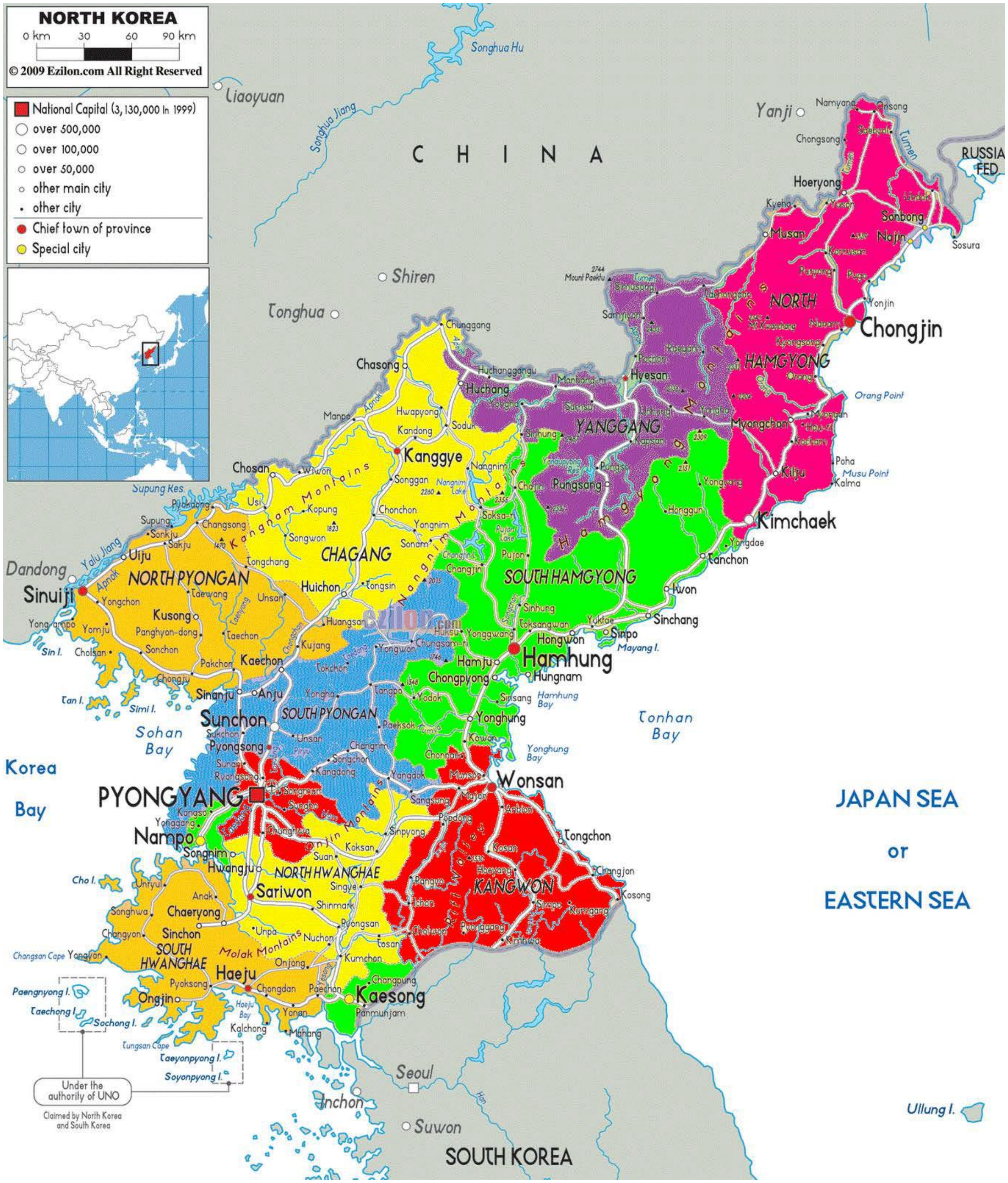
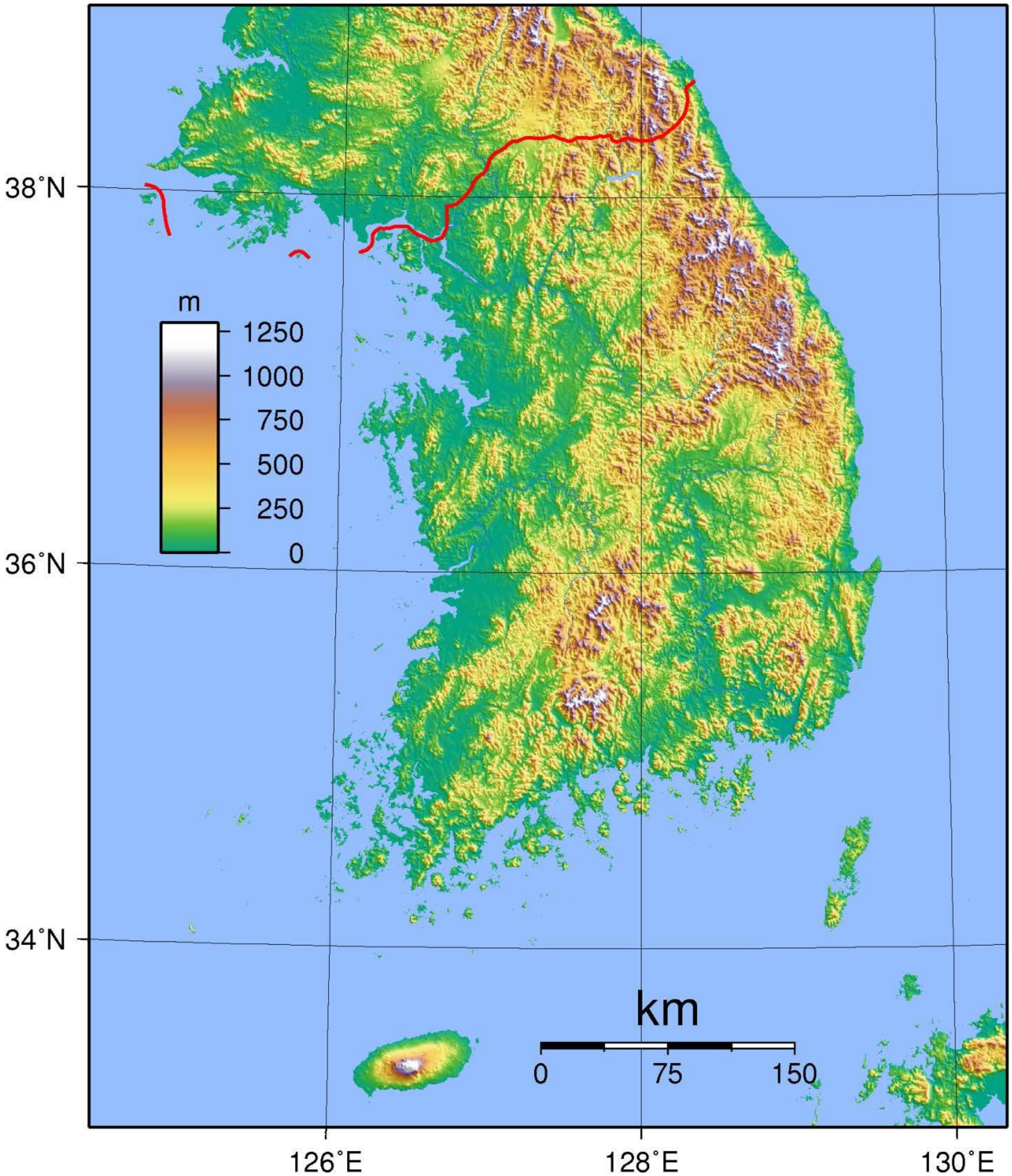


1. DPRK political map



2. Topography of the ROK

3. Topography of the DPRK

4. ROK political map

5. ROK mountain ranges